

HEART.

A JOURNAL FOR THE STUDY OF THE CIRCULATION.

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A MYOCARDIOGRAPH FOR THE MAMMALIAN HEART.

BY ARTHUR R. CUSHNY.

THE myocardiograph which I have used for a number of years to record the movements of the mammalian heart is a modification of the one devised by Roy and Adami, and, like it, is designed to record the changes in the distance between two points on the heart's surface, while any other movements do not affect it. For this purpose two points on the surface of the heart are attached to the ends B and L of the apparatus (Fig. 1), and contraction of the fibres between these points causes an approximation of L to B and a corresponding withdrawal of K from C. A light thread attached to K and passing over the pulley is thus drawn upon and pulls down the writing lever, which is arranged to record on smoked paper.

AB is a light magnalium rod suspended from a horizontal bar by means of a gimbal joint at A and pierced at B to admit of the attachment of a fine thread. The point B can move freely in the plane perpendicular to AB, but as a matter of fact, its movements are very limited when it is attached to the heart. AB passes through a thin tube CD, which fits it accurately and is interrupted in the middle to admit of a collar E; this is unattached to CD but is fixed on the rod AB by a screw and thus supports CD at a definite height while permitting it to rotate about three-fourths of its circumference round AB. The upper part of CD bears a small vulcanite pulley over which a thread is run. From the lower half of CD, in the earlier forms of the apparatus, there projected a bar DH ending in axes on which a light lever LK was pivoted. In the newer form the length of this bar can be altered by sliding it into a sheath; during an experiment its length is fixed by means of a set screw. The bar ends in two axes which carry a short piece of tubing forming a sheath in which the magnalium rod KL can be moved up and down for adjustment to the heart; after the attachment to the heart is made, this movement is prevented by a set screw, and the rod KL can only move in the axes on which the sheath is pivoted. At L the rod is pierced for attachment to the heart, and at K for the thread to the writing lever*.

To adjust the apparatus to the heart a large number of changes may be made, but these are seldom necessary. Thus KL may be pushed up or down in the sheath, when it is necessary to have L at a higher or lower level than B.

* I have sometimes substituted for the pulley and vertical string a tambour attached to C D, the string from K pulling on the membrane; the movement is then transmitted to a recording tambour in the usual way.

The distance between the fulcrum on which KL is pivoted and AB may be altered by pushing the solid bar into the sheath. Or, by loosening the screw on the collar at E, the whole of the parts supported by the sheath CD may be moved along AB. As a matter of fact but little adjustment is required for ordinary records, but occasionally, in taking tracings of the movements of the left heart, it may be necessary to alter the positions of the points of attachment. While a record is being taken, all three set screws are screwed home, so that the only movements possible are those around the gimbal joint at A, that around the axis AB, and the movements of the lever LK on its fulcrum at H. The first two movements are very slight, however, and the last may be taken to be that recorded for all practical purposes.

In investigating the effects of electrical stimulation of the heart, it is convenient to use the rods AB and KL as electrodes, and for this purpose one wire is attached to the horizontal rod supporting AB by means of a screw connection not shown in the figure. The other is connected in the same way to the horizontal bar near H. These points are insulated by vulcanite blocks at I and I².

The writing lever is pulled downward by the contraction of the heart, and is restored to its position by a spring or weight. For ordinary work I use a light spring as shown in the figure. It is attached to a short upright on the writing lever at one end and to a collar which can be slid along the bar of the horizontal support. A change in the tension exerted on the lever and on the heart muscle is thus permitted.

When it is desirable to have the systole recorded by an upright movement, this can be done by interposing a pulley on the course of the thread.

To record the movements of two chambers of the heart simultaneously the whole apparatus has to be duplicated except the supporting standard.

Unless pulleys are used it is essential that the thread should be vertical, that is, that the heart should lie directly beneath the writing lever. This can be best arranged by using some form of kymograph adapted for long blackened paper, and swinging it free from the table so that the operating board lies directly beneath the drum, and the long axis of the kymograph stands at right angles to its ordinary position.

The myocardiograph is best suited for the dog's heart, but can also be applied to the cat. In the former, I find that the best anæsthesia is obtained by giving a large dose of morphine hypodermically half an hour before the operation and following it by paraldehyde given by the stomach tube, 10 to 15 g. Tracheotomy is performed and the skin and subcutaneous tissues divided in the middle line along the sternum, which is then split longitudinally by saw or bone forceps. The two sides of the chest are held apart by strings and weights, and the pericardium is picked up, divided longitudinally and sewn to the edges of the sternum so as to form a cradle in which the heart lies. Stitches are then placed in the epicardium of the right ventricle and auricle, care being taken that the needle does not penetrate

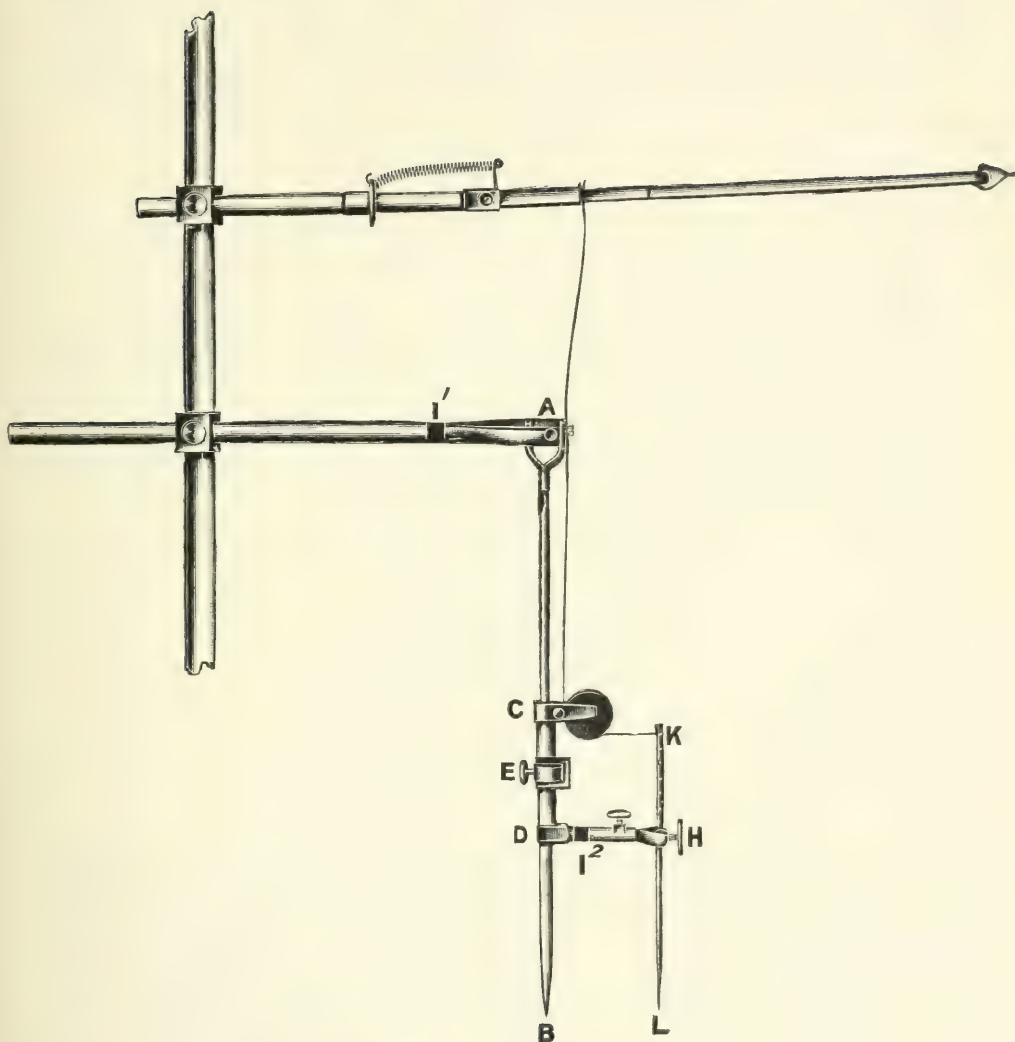


Fig. 1.

the whole thickness of the wall of the latter. The myocardiograph levers are then attached, the strings are passed over the pulleys and fixed to the writing levers by beeswax, and the record may be begun. The attachment of the levers occupies only from 5 to 10 minutes as the apparatus seldom requires much adjustment. The left heart may be recorded instead of the right, but is less readily accessible.

The apparatus may also be applied to record the movements of the uterus and intestine.

The myocardiograph is made by Mr. C. F. Palmer, 6, Upper Tulse Hill, London, S.W.

METHODS FOR SECURING WHOLLY NORMAL MANOMETRIC BLOOD-PRESSURE TRACINGS FROM THE QUIESCENT ANIMAL.

BY CLYDE BROOKS.

(*From the Hull Laboratory of Experimental Therapeutics,
University of Chicago.*)

THE methods described are those designed for securing direct manometric blood-pressure tracings painlessly and from the unanæsthetized animal.

Three different methods have been adopted. The first consisted in the use of a T-shaped cannula; the second involved the introduction of an ordinary three-way cannula after the isolation and preparation of the artery under general anæsthesia and after allowing time for recovery from the anæsthetic; and the third involved the employment of a trocar cannula.

It was thought that since thin glass tubes can be tolerated in the lumen of blood-vessels for several weeks without the occurrence of clotting¹ it ought to be possible to insert a T-shaped cannula (Fig. 1) between the ends

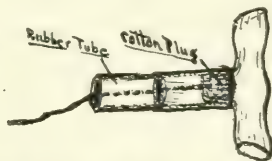


Fig. 1. Model of T-cannula, with a cotton plug in the side arm, for taking manometric blood-pressure tracings.

of a cut carotid artery, to restore the continuity of the vessel, and to bring the side arm through the skin; and that after the recovery of the animal from the anæsthetic and the operation it might be feasible to take tracings of the blood-pressure by connecting the side arm with a manometer. In carrying out this plan a number of dogs of various sizes were used. The dogs were anæsthetized with ether and operated upon under asepsis. The T-shaped cannula, short and thin-walled, was made of such size as to fit snugly into the artery. The side arm was closed with a cotton plug which was saturated with paraffin oil and connected with a handle so arranged that the entire plug could be drawn out when it was desired to make the connections with the manometer and pressure bottle. After tying the cannula into the artery, it was brought up close under the skin and the wound closed, leaving the side arm protruding. The wound was dressed

with dry gauze and the dog allowed to recover from the effects of the anæsthetic. The time allowed for recovery was usually twenty-four hours ; but some dogs having been operated upon during the forenoon were used in the afternoon of the same day, and some were used three or four days after the initial operation. When an observation was desired the dog was usually placed upon its right side and kept as quiet as possible by stroking and patting while the plug was drawn out of the side arm and the T-cannula connected with the manometer and pressure bottle. As soon as the connections were all properly established the tracing was taken upon a kymograph drum in the usual way. The management was the same as in ordinary blood-pressure work except that the dog had to be watched and gently restrained by caressing and patting when restless or when inclined to rise to its feet. Some dogs were quieter when allowed to stand upon their feet or sit upon their haunches while the blood-pressure was being taken. As a rule little trouble was experienced in persuading the animal to remain tranquil. The method of manipulating the cotton plug was very simple. When about to take an observation, in order to prevent the occurrence of hæmorrhage while withdrawing the plug, the short indiarubber tube of the side arm, shown in Fig. 1, was grasped and compressed while the plug was being withdrawn and while the free end of the glass connection from the manometer and pressure bottle was quickly pushed into the end of the rubber tube. As soon as sufficient pressure had been turned on from the bottle, the compression of the rubber tube was discontinued and the tracing begun. In replacing the plug after the observation had been completed, the rubber tube of the side arm was again grasped and compressed while the glass connection from the manometer and pressure bottle was withdrawn ; and the cotton plug, which had in the meantime been cleansed in and resaturated with paraffin oil, was grasped with a forceps and pushed down the lumen of the side arm to its proper position.

In some cases tracings were taken from the same dog on successive days ; but at times when this was attempted it was found that clotting had occurred. This was especially the case when the artery had been much handled. If care is taken in the manipulation of the vessel, tracings may usually be taken on at least three or four successive days.

The second method, the most useful in laboratory experiments where a single observation is required, was a slight modification of the first method. In a preliminary aseptic operation under ether the left carotid artery was isolated for several inches and brought up close under the skin and the wound closed. On the following day, or after recovery from the anæsthetic, an ordinary three-way cannula was tied into the artery and the blood-pressure taken in the usual way. (In order to avoid all possibility of causing the slightest pain, cocaine may be applied locally during this part of the work ; but it is not necessary, for the animals show no evidence of pain even when cocaine is not used.) By this method only one observation from each animal can be obtained.

The third method consisted in the use of a trocar cannula (Fig. 2). This method is the most useful where brief and successive observations are to be made for a number of days, or especially where it is desirable to use different arteries of the same animal. For example, this method might be employed in determining from day to day the changes in blood-pressure in a dog subjected to experimental nephritis; or it might also be employed in comparing simultaneous blood-pressure tracings taken from several different arteries of the same animal.

Bardier² has invented a trocar cannula for blood-pressure work, but it is not adapted for use upon the intact animal.

Our trocar cannula is made of steel. It is used by first inserting the instrument with the obturator in position, after which the obturator is entirely removed, leaving the end of the cannula within the lumen of the blood-vessel. The other end of the cannula is connected by a rubber tube with the manometer and pressure bottle. A segment from the distal end of this rubber tube in connection with the trocar cannula is shown in Fig. 2. The bristle which is shown in the drawing is not used, of course,



Fig. 2. Diagram showing trocar cannula for taking manometric blood-pressure tracings. The obturator is shown thrust through the rubber tube into which the trocar is inserted. The other end of the rubber tube connects with the manometer and pressure bottle. The bristle shows the course of the hole running lengthwise through the obturator, beginning at the point and coming out at the side hole.

except to keep the interior of the obturator oiled and in good condition when not in use.

In carrying out the method the end of the trocar cannula was inserted into the lumen of the carotid artery, which by previous operation had been isolated and brought up close under the surface of the skin as described above, or in other cases it was inserted into the femoral artery of a normal intact dog. The obturator had a small hole running lengthwise through it in order that the operator could tell when its point was within the lumen of the blood-vessel by the blood escaping from the side hole near the other end of the obturator. After the pressure from the bottle had been turned on for an instant to raise the pressure in the manometer and cannula, the obturator was entirely withdrawn and the tracing taken. When the observation was completed the artery was firmly compressed over the site of the puncture while the cannula was being withdrawn. This was done in order to prevent the formation of a hæmatoma. The compression of the artery was maintained for at least five minutes after the removal of the cannula in order to allow time for complete occlusion of the puncture wound in the blood-vessel. Massage movements were combined with compression in order to draw the adventitia of the artery over the puncture in the wall of the blood-vessel made by the instrument.

By the use of one or other method it is possible to take manometric blood-pressure tracings showing the behaviour of the blood-pressure of the normal intact animal under the influence of normal stimuli, changes in environment, emotion, etc.; moreover, the action of certain drugs upon the circulation can be investigated in the absence of those changes in the vasomotor and cardiac mechanisms which are induced by anæsthetics and hypnotics. Fig. 3 is a tracing showing the effect of the administration of

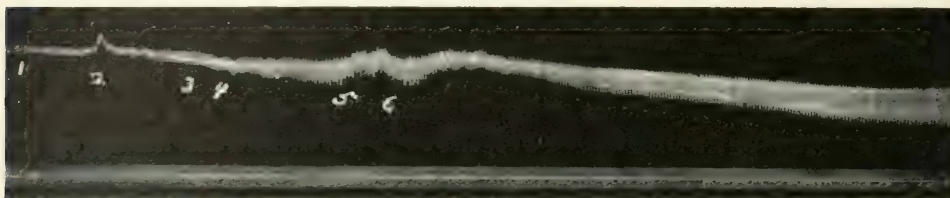


Fig. 3. $\times \frac{1}{2}$ linear. Tracing showing the effect of the administration of alcohol by the mouth upon the blood-pressure of a dog anesthetized with ether. 1-3, Normal tracing. 2, Turning dog upon its right side. 4, Poured 25 c.c. of 50 per cent. alcohol into the left buccal cavity. 5-6, Raised head and manipulated pharynx. Base line and time marked in seconds.

alcohol by the mouth upon the blood-pressure of an anæsthetized animal; while Fig. 4 is a tracing showing the effect of alcohol administered in a

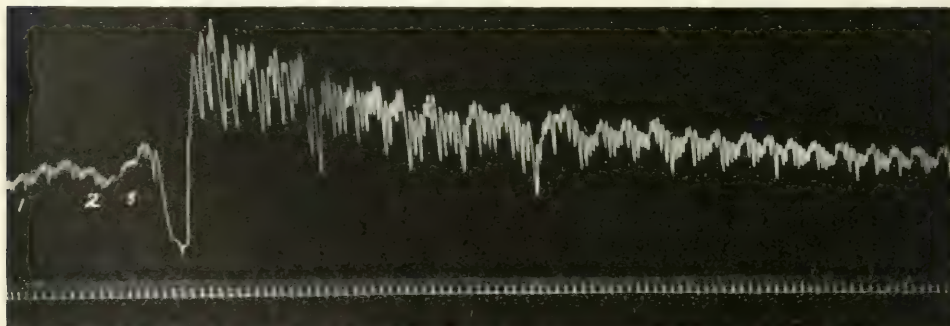


Fig. 4. $\times \frac{1}{2}$ linear. Tracing showing the effect of the administration of alcohol by the mouth upon the normal unanesthetized dog. 1-2, Normal tracing. 2-3, 10 c.c. of 50 per cent. alcohol given by the mouth. Base line and time marked in seconds.

similar manner upon a normal quiescent unanæsthetized animal.

Studies will be made on the physiology and the pharmacology of the circulation to which these methods seem applicable.

It gives me pleasure to express my thanks to Dr. Samuel A. Matthews especially for his valuable assistance in the surgical work, and to him and Dr. Anton J. Carlson for their interest and counsel and for criticism of the manuscript.

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A SCHEME FOR INVESTIGATING THE EFFECTS OF TREATMENT ON THE HUMAN HEART.

By JAMES MACKENZIE.

(*London.*)

A PRELIMINARY inquiry into the action of drugs on the human heart, pursued when engaged in general practice, showed me that it was possible to ascertain the manner in which certain drugs acted on the human heart with considerable accuracy, and from the evidence thus obtained certain conclusions could be drawn which explained many of the obscure actions which have given rise to the confusing and contradictory statements in regard to the action of cardiac drugs.

When I was appointed physician to the Mount Vernon Hospital for diseases of the chest, and given charge of the wards devoted to diseases of the heart, I embraced the opportunity of pursuing the study of the action of cardiac drugs under circumstances far more favourable than when engaged in general practice. I was fortunate in being able to have associated with me Professor Cushny, who has placed his knowledge of drugs at our service, who has guided us in their administration, and who has experimentally tested in his laboratory the efficiency of the remedies we used. To ensure accuracy in diagnosis Dr. Lewis has kindly examined many of our patients by means of the electrocardiograph. The minute and careful study of individual cases, and the employment of graphic methods for recording the movements of the heart and vessels, is extremely laborious and time-robbing, and could not have been accomplished without the assistance of Dr. Hulme Turnbull and a number of colleagues who were trained to assist us.

In seeking for a definite standard to guide us in our observations there are two matters which are of the first consideration, namely, to have a clear idea of what is meant by heart failure, and to recognise the true significance of abnormal signs or symptoms. These two matters are so often confused that an abnormal sign, such as a murmur or irregularity, with or without heart failure, is regarded as evidence of "heart disease," and as a defect needing treatment. While carefully noting the presence of abnormal symptoms, we sought for other evidence whereby to estimate the functional efficiency of the heart.

In order to obtain a clear understanding of heart failure, not only for diagnostic purposes but to serve as a guide to treatment, we must have

EXAMINATION OF HEART	TENDERNESS	EXAMINATION OF LUNGS	URINE	REMARKS

the Mount Vernon Hospital.

exertion is employed, as, for example, the ascent of a given number of steps, and a note is made of the patient's sensations, while records of the circulatory and respiratory movements before and after the exertion are obtained. Improvement can then be found to be associated with a number of collateral signs, and may be noted in the chart to which I shall shortly refer.

The method of taking the rest power and work power as standards, not only in carrying on such an investigation as I am describing, but in everyday practice, will be found of great value, especially when some abnormal phenomenon is presented the nature of which is not understood. The more usual method of judging the heart by studying each case from the point of view of compensation and decompensation, or failure of compensation, is unsatisfactory, for the idea conveyed by these terms is too indefinite to be of value, while the sense in which they are commonly used is actually misleading.

In order to facilitate the taking and preservation of accurate records, we have utilised a special chart, in which spaces for the more salient features are filled in the routine of daily examination. A glance at the chart (see top of pages 10 and 11) reveals its object, and I need only dwell on a few points. It omits a reference to the changes in rhythm, for the graphic records are kept on a separate sheet. These records are peculiarly valuable as they form a permanent register of the manner in which the drug affects the heart, as in the instances of slowing of rate, or of the production of some characteristic irregularity. Taking a tracing continuously for ten or fifteen minutes has been of special service in two ways. The first effect of digitalis often consists of an *occasional* alteration of the rhythm of the heart, and in observations limited to a few minutes the alteration at rare intervals may escape detection. The occurrence of an extra-systole or a dropped beat as the result of partial heart-block (a not uncommon occurrence with drugs of the digitalis group) may be instanced. In long records taken immediately after exertion we obtain the most valuable indications. We have found that the peculiar action of such a drug as digitalis is first detected as the heart slows from the rapid rate following upon exertion. These reactions vary in different patients, and in some patients they are of a varied character. But they are frequently fugitive.

The column for recording the patient's sensations is of particular value in view of what I have said in regard to the estimate of the condition of the work power, and so far it has been instructive to observe the improvement coincident with the changes recorded in the remaining columns.

The blood-pressure measurements are taken by means of a Martin's modification of the Riva-Rocci apparatus, and, as far as possible, one observer is responsible for the observation in each case. The reason for this is that there is a distinct difference in the ability of different individuals to appreciate the earliest reappearance of the pulse after it has been obliterated, and for purposes of comparison it is better to avoid the possibility of variation due to this cause. While we only note what is called the systolic pressure in each case, we recognise that the pressure at which the first pulse beat is observed does not represent the actual systolic pressure within the artery, but as a definite point of observation it is of value, and the most reliable which our present methods afford. We are careful to exclude the records of the blood-pressure when the pulse is continuously irregular, inasmuch as the pulse beats are always varying in strength, and no satisfactory conclusion can be arrived at from the strongest or weakest beat. While no doubt a record could be obtained which might possess some value, yet in view of the fact that such record would give a seeming reliability which in reality it does not possess, we reject such observations lest they should tend to mislead.

In noting changes in the size of the heart, we use percussion alone, as being on the whole the most convenient and the most reliable. I had used the X-rays for some years, but they did not render the help I had hoped for. A further inquiry into the use of the orthodiagraph and photographic methods gave me the impression that the results were not sufficiently precise for my purpose, and I was therefore forced to content myself with percussion, in preference to methods which are troublesome and laborious and which do not yield correspondingly accurate results.

Another feature which calls for a short reference is the space left for noting changes in the sensibility of the external body wall. I had long observed that in some forms of heart failure the tissues in certain regions become tender on pressure, and I found a distinct relation between the degree of heart failure and the extent or severity of the hyperalgesia of the skin muscles, mammary gland and other tissues in the external body wall. In fact the first sign of improvement in the patient's condition is nearly always the diminution of the tenderness of these areas. The most frequent sites of manifestation are beneath the left breast, the breast itself, the pectoralis major muscle where it forms the anterior wall of the axilla, the sterno-mastoid and trapezius muscle on the left side and the skin covering these. While such areas can be correlated with definite changes in the heart, equally striking symptoms are presented when the liver is enlarged, and the marked diminution of the hyperalgesia of the tissues and the external body wall covering the liver, always accompanies a decrease in the size of that organ.

The form of drug and method of administration we employ are those which are most commonly used by the practitioner in his everyday work. We felt that the employment of hypodermic or intra-venous injections, methods of great value, and which we may later and under special circumstances employ, would not result in that usefulness to the general practitioner ensured by following the more universal administration by the mouth. Also the drugs used are those most commonly employed in practice. In the case of digitalis, strophanthus and squills the B. P. tincture was employed, as being on the whole the most reliable. The extractives which go under such names as Digitalin, Digitoxin, Strophanthine, we have not used, because Professor Cushny pointed out that none of these glucosides are sufficiently definite to be recognised, that a preparation like the tincture contains the different glucosides, and that there is no reason to suppose that the special preparations have any distinctive advantage.

As far as possible we are careful to eliminate adventitious circumstances, such as rest and diet, in our use of the drug, and in our consideration of its effect. For this purpose the patient is allowed to remain at rest for a period before the drug is administered. In this way we also study the effect of rest in treatment, and, as is well known, it is a very powerful remedy in a great variety of cases.

We attempt the comparison of effects of different doses of the same drug, and of different drugs on the same individual. In suitable cases, where we get a definite and well-recognised reaction from such a drug as digitalis, we note the amount of the drug taken to produce the first physiological effect, and the quantity that maintains the heart in the condition best fitted to carry on the circulation efficiently. It may be found that a given quantity of the drug has slowed the pulse from 100 to 60 beats per minute, and coincident with this slowing there has been an improvement in the patient's condition. If the drug be pushed further the pulse may become still slower in its rate, but the patient may not feel so well, being conscious of the thumping of the heart, or more breathless. Under such circumstances we gradually diminish the dose till we find the quantity which keeps the rate such that the patient feels most comfortable. It is very remarkable how reliable a patient's sensations are in this matter, so much so that we are often guided solely by him as to the quantity of drug which he continues to take. When digitalis produces nausea, or for other reasons, we let the patient escape from the influence of the drug, and then substitute some other drug, as strophanthus, squills, helleborein, and carefully push the drug until the first physiological effect is produced and the patient experiences an improvement in his condition. By this means we obtain a knowledge of the reaction of the patient to the different drugs, and find out which, for him, is the most beneficial. We are thus enabled to form an opinion of the properties of the different drugs, the most appropriate doses, and their relative efficiency in treatment. The drugs are then tested and physiologically assayed.

There are other features in heart failure which call for further inquiry, such as cyanosis and the nature of different forms of breathlessness. We have attempted in several ways to deal with these questions, but at present we find our methods insufficient to cope with the subject. We hope that we shall be able to evolve methods which will assist in these enquiries.

CARDIAC IRREGULARITIES PRODUCED BY SQUILLS.

By H. HUME TURNBULL.

(*From Dr. Mackenzie's clinic at Mount Vernon Hospital for
Diseases of the Chest.*)

It has been shown that heart-block and other irregularities of the heart may be produced in certain patients by the administration of digitalis^{3 & 4} but very little is known as to the action of the other members of the digitalis group of drugs in this respect. The following record shows that squills may produce heart-block in suitable cases, and also many other phenomena of a nature akin to those produced by digitalis.

M. T., a single woman, aged 24, was admitted to the Mount Vernon Hospital on 23rd February, 1910, complaining of palpitation and shortness of breath. As a child she had suffered from scarlet fever; she had rheumatic fever at the age of twelve, and chorea at fourteen, and about eight years ago she "swelled up all over." For this swelling she attended the out-patient department at St. George's Hospital for some weeks, but was not confined to bed. She frequently has painless swelling of one or both sides of the face. She has never been strong, always feeling weak and tired, especially in the afternoons, though in the evenings she feels better again. After the least exertion she is very short of breath and her heart palpitates unpleasantly; this has been getting gradually worse for the past five months, and has been much worse since an attack of influenza at Christmas. She has had no cough, and no pain in the chest or elsewhere. She can sleep well with three pillows, but cannot breathe comfortably with less than three.

There was no history of rheumatism or chorea in the family; the father died of phthisis, while her mother, four brothers and one sister are healthy.

The Examination on admission.—The patient was a woman of middle height, pale, but well nourished, the skin being of a faint lemon-yellow colour, and the mucus membranes slightly pale. Her teeth were in a bad condition, many being carious, with some sepsis around the gum margins. The chest was markedly asymmetric, the right costal cartilages being very prominent. The heart's apex was in the 5th interspace $5\frac{3}{4}$ inches to the left of the middle line, and the cardiac dulness extended 2 inches to the right of the

sternum and upwards to the 3rd left rib. The apex beat was forcible, and a well-marked diastolic thrill was felt at this point. On auscultation at the mitral area a loud crescendo murmur was heard running up to the first sound, which was followed by a soft systolic murmur conducted outwards, and then a long diastolic murmur. A soft systolic murmur was to be heard at the tricuspid area, and the sounds at the base were clear, the pulmonary second being markedly accentuated. There was no tenderness on pressure over any part of the chest.

The blood showed no abnormality except a slight increase of the polymorphonuclear leucocytes. The examination revealed no other abnormality. Urine : Sp. Gr. 1020, reaction acid, no albumen or sugar.

Tracings taken at this time showed a regular pulse of 70 per minute, with a normal venous curve, the *a-c* interval being 0.2 sec.. Respirations at rest were 16 per minute, and the systolic blood-pressure was 114 mm. of mercury. After a walk up a flight of twenty stairs the pulse quickened to 122 per minute for about two minutes, and then slowed down again to 70-80. There was slight dyspnoea after exercise.

Subsequent observations.—The patient improved with rest, and the dyspnoea was so much less that five days after admission she could lie quite flat without discomfort, and the cardiac dulness had decreased to $1\frac{1}{4}$ inches to the right, and $5\frac{1}{2}$ inches to the left of the middle line.

Administration of digitalis.—On the 6th of March she began taking 1 dr. of the tincture of digitalis per day, which was continued till the 18th. This produced slowing of the pulse to 40-46 per minute with marked sinus arrhythmia, which was independent of respiration, and increased by exercise; the nature of this irregularity will be considered later. After exercise the heart beat very rapidly for a few minutes, then decreased in rate, with frequent extrasystoles, but the *a-c* interval was only slightly increased, and the blocking of an auricular impulse in its passage over the auriculo-ventricular bundle was detected on one occasion only.

The patient's condition improved very much during this period and dyspnoea on exertion and palpitation almost disappeared. All drugs were omitted from 18th March to 1st April.

Administration of Squills.—On 1st April, as the palpitation had reappeared and she was a little short of breath, she was given 1 dr. of the tincture of squills per day in four 15-minim doses.

Upon the first day of administration the pulse rate was 96, respiration 24, and systolic blood-pressure 120 mm. Hg., and the cardiac signs were unaltered. The *a-c* interval was 0.2 sec. (see Fig. 1).

On 10th April, after taking 9 drs. of the drug the pulse was 45 per minute, the rhythmic irregularity had reappeared, and was much more marked after exercise. This is well shown in the tracings (Figs. 2 and 3), the first of which shows that the slowing is due to a standstill of the whole heart from an alteration of the sinus rhythm; and the second that it is not dependent upon respiration. This observation is interesting and marks a difference between

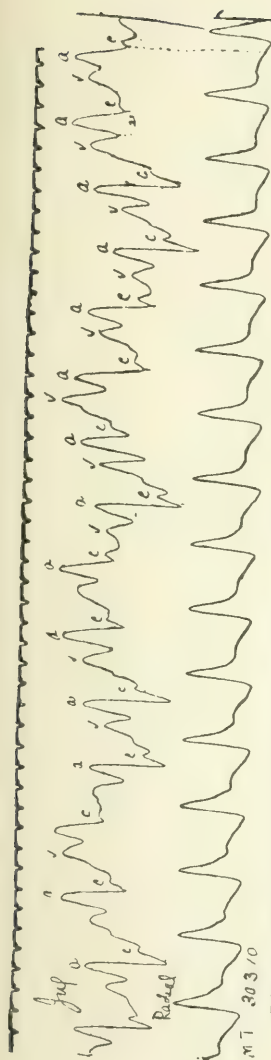


Fig. 1. Shows the condition before the administration of squills was commenced. The pulse is regular and the a-c interval normal, 0.2 sec.

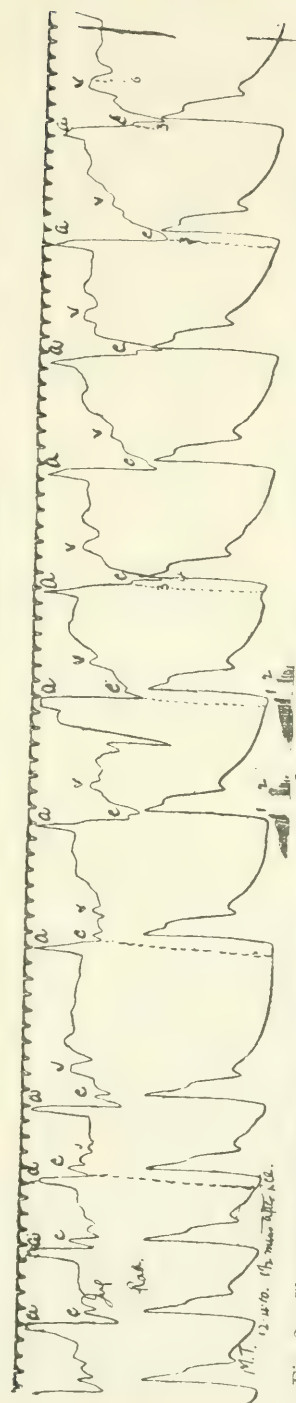


Fig. 2. Showing the condition a minute and a half after exercise and the onset of slow rhythm, in which the whole heart is affected. Each auricular beat is followed by a ventricular contraction, and there is no sign of heart-block. Below the tracing the sounds heard on auscultation are represented.

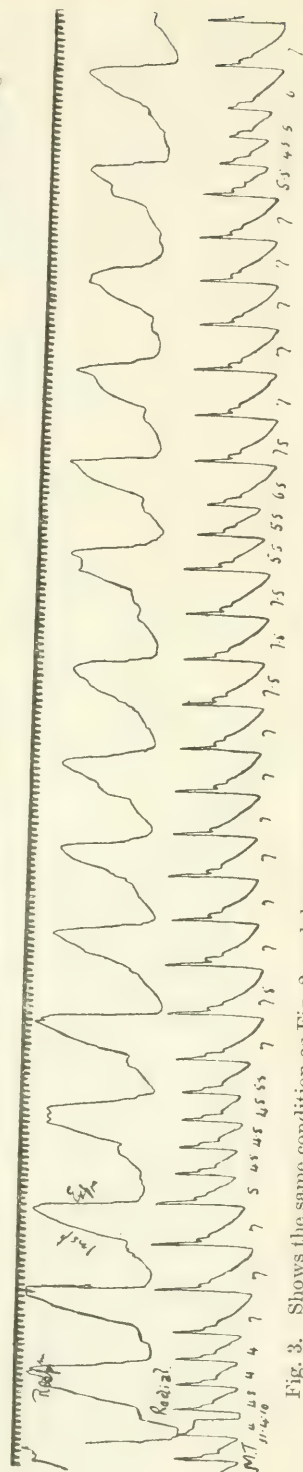


Fig. 3. Shows the same condition as Fig. 2, and demonstrates the fact that the sinus arrhythmia is independent of respiration, and that both the fast and slow phases may extend over more than one respiratory cycle.

the artificially induced arrhythmia and that which is so common in children and young adults (Mackenzie's "Youthful Irregularity"). In the youthful form the cardiac rhythm is usually dependent on respiration, and disappears on holding the breath; but here one rate is maintained during several complete respiratory cycles.

The first instance of blocking of auricular impulses occurred on April the 12th, after 11 drs. of tincture of squills had been taken, and is illustrated in Fig. 5. This and the next two tracings will be considered together, but first it is of interest to notice the earlier part of this same tracing (Fig. 4),

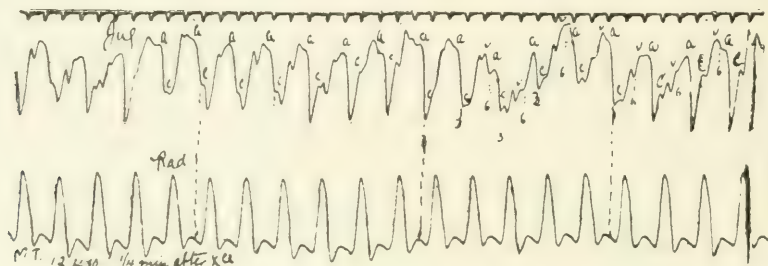


Fig. 4. Showing the condition shortly after exercise, while the pulse was fast and regular. All auricular impulses reach the ventricle, and the *a-c* interval is less than 0.2 sec.,

showing the condition one minute after exercise, when the heart was beating rapidly and regularly, all the auricular impulses passing through to the ventricle. In electrocardiograms taken at this stage the P-R interval was 0.18 sec.,

The three tracings (Figs. 5, 6 and 7) show varying degrees of heart-block, Fig. 6 showing only an occasional missed beat, while in Fig. 5 every fifth or every third impulse is blocked, and in Fig. 7 the ventricle fails to respond, at first to every third, and then to every second auricular impulse. There is a slight irregularity in the incidence of auricular contraction, but this is not great enough to affect the passage of impulses along the bundle, the longest pauses giving only a very slight increase in the interval of rest. The *a-c* interval is greater than the normal at this period, but in most cases it is shortened somewhat after a block and then lengthens out again, but this is not well marked either in the venous or the electrocardiographic curves. The heart-block is well shown in the electrocardiogram, which was kindly taken for me by Dr. Thomas Lewis at University College Medical School (Fig. 8).

Records of the apex beat taken after exercise showed a standstill of the ventricle during the pulse pauses; and on auscultation there was sometimes a complete silence, but usually a long crescendo murmur could be heard, beginning a short time after the diastolic murmur and ending abruptly, and not followed by a first sound; then there was a considerable pause and another crescendo murmur followed by the first sound. During the beats preceding a block an appreciable interval could be made out between the end of the

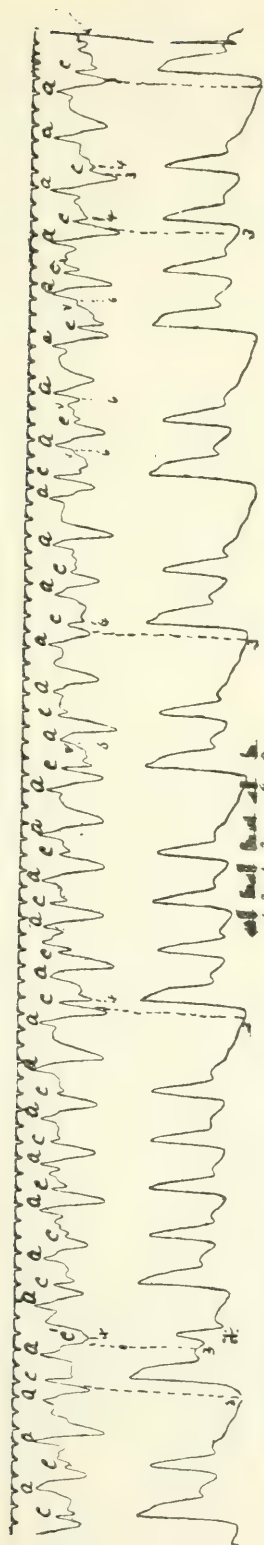


Fig. 5. $\times \frac{1}{2}$ linear. Tracing taken 12-4-10, 4 minutes after exercise. A slight sinus arrhythmia is present, but the long pauses in the radial pulse are due to heart-block. The beat marked * is a little premature and may be due to an extrasystole, but the sinus arrhythmia makes it possible to explain the beat as a normal one.

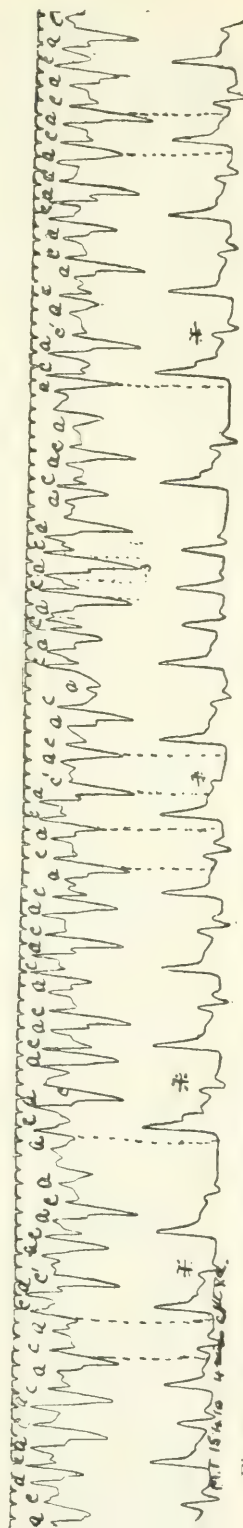


Fig. 6. $\times \frac{1}{2}$ linear. A complex irregularity, in which heart-block is distinct, and in which either extrasystoles or heart alternation is also present.

crescendo murmur and the beginning of the first sound. These observations appear to demonstrate the production of the crescendo murmur by the auricular systole in this case. (Compare Cohn¹ and Griffiths and Cohn².) This is represented diagrammatically under Fig. 5. During this time the patient was feeling extremely well, and there was no giddiness or dyspnœa, and no abnormal sensation of any kind, even while the heart-block was present, though she was conscious of palpitation during the rapid heart action which immediately followed exercise.

It is interesting to note that the pulse always remained perfectly regular while the patient was at rest, the only abnormality being a slight increase of the *a-c* interval.

The partial heart-block which occurred after exertion appeared to be due to an increase in the action of the vagus, depressing the conductivity of an already slightly damaged bundle; the facts on which this opinion is based are as follows:—

(1) During the period of rapid heart action immediately following exercise the pulse remained perfectly regular, and, though stimuli were falling on the bundle with great rapidity, all were transmitted to the ventricle and the rate of conduction did not differ from that of normal cases.

(2) Heart-block occurred when the rate of the heart beat was slowed a few minutes after exercise.

These two points suggest that the depression of conductivity was due chiefly to vagal inhibition, for the damage to the bundle itself either by disease or direct poisoning with the drug was but slight. Furthermore, it is a matter of experience that sinus irregularity, due almost certainly to change in vagal tone, is peculiarly apt to be manifested in perfectly healthy people on the subsidence of the initial quickening after exercise, and is evident in very many cases under the influence of digitalis.

Besides the heart-block a further form of irregularity will be noticed in Figs. 5 and 6. It is best shown in Fig. 6. In this tracing a marked alternation is seen in the size of the radial pulse beats in the greater part of the curve. In the majority of cases the pauses before and after the small beats are equal, and each ventricular contraction is preceded by a contraction of the auricle, so that the condition is precisely similar to that of Pulsus Alternans. However, the beats marked * in Figs. 5 and 6 appear earlier and are followed by longer pauses, and this phenomenon gives rise to the suspicion that they may be due to extrasystoles. Very little help is gained from a study of the venous pulse, as all the beats are preceded by an auricular wave, and the slight degree of sinus arrhythmia which exists throughout the curve makes it extremely difficult to say whether any given beat is premature or not. An argument in favour of the condition being really one of heart alternation is to be found in the fact that the distance between a large beat and a small beat during the alternation is the same as that between two normal beats of equal size in the tracing immediately after the irregularity has

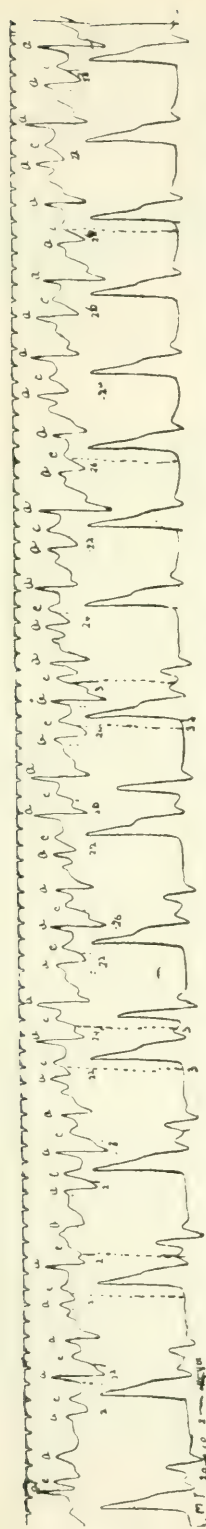


Fig. 7. $\times 1$ linear. Tracing taken 2 minutes after exercise on April 20th, when the patient had taken 19 drs. of the tincture of squills. It shows at first a 3:2 and then a 2:1 heart-block, with slight sinus arrhythmia. The a-c interval varies in length, but is seen to be shortened after the pause in the earlier part of the tracing.

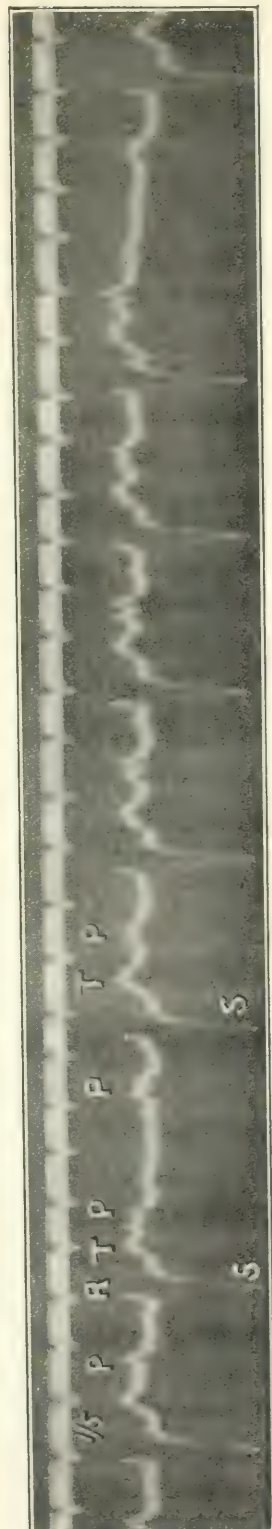


Fig. 8. $\times 1$ linear. Electrocardiogram from right arm and left arm taken about 3 minutes after exercise. It shows the variations P, due to auricular systole; each P variation shows the splitting characteristic of mitral stenosis. It shows the variations R, S & T, representatives of ventricular contraction. The P-R intervals are increased from the normal 0.14—0.16 sec. to 0.3 sec. There are two dropped beats.

disappeared. The electrocardiograms throw little light on this subject. Only one isolated ventricular extrasystole was recorded after exercise, and there was no alternation in the size of the succeeding ventricular peaks. At the same time it is known that alternation in the ventricular peaks of the electrocardiogram may be absent in cases which show well-marked alternation in the radial pulse.

The squills was stopped on 21st April, after the patient had had 20 drs., as she was complaining of headache, loss of appetite, and general malaise. Two days after the drug was withdrawn no trace of the irregularities remained.

CONCLUSIONS.

1. In certain cases full doses of squills will produce :—

- (i) Sinus arrhythmia.
- (ii) Heart-block.
- (iii) An irregularity whose nature cannot be decided with certainty, but which may be a condition of heart alternation, or may be due to extrasystoles.

2. The heart-block which occurs as a result of the administration of squills is due principally to a depression of the function of conductivity in the auriculo-ventricular bundle by the action of the vagus, and very slightly, if at all, by a direct poisoning of the bundle fibres by the drug.

3. The irregularities attributed to the vagus are most prominent a few minutes after exercise.

4. The irregularities produced by squills are unaccompanied by any discomfort.

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GALVANOMETRIC CURVES YIELDED BY CARDIAC BEATS GENERATED IN VARIOUS AREAS OF THE AURICULAR MUSCULATURE. THE PACE-MAKER OF THE HEART.*

By THOMAS LEWIS.

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THE observations upon which the present communication is based have been of two kinds, experimental and clinical. The results of the examination of a number of patients, and a number of animals under experimental conditions, are described side by side†.

The normal heart beat originates, as will be subsequently demonstrated, in the neighbourhood of the junction of superior vena cava and right auricle. The contraction travels from this point by a channel as yet indeterminate to the tissue uniting auricle and ventricle (the auriculo-ventricular bundle), and it is thence propagated by means of the bundle, its branches and the arborisations and network of the Purkinje system to the main mass of the ventricular musculature. The normal and regular rhythm of the heart may be disturbed, as is now universally recognised, by contractions dependent upon pathological impulse formation in the heart wall. And, as may be shown by mechanical records from auricle and ventricle, such impulse formation may have its seat in auricle, in ventricle, or in the tissues uniting the two chambers. The present paper is confined to a further discussion of such impulse formation in the auricle, for by galvanometric methods a closer identification of the seat of such impulse formation is possible.

As the normal heart beat consists of an auricular and ventricular systole, so the normal electrocardiogram is composed of two distinct portions, one dependent upon the auricular the other upon the ventricular contraction. An ectopic‡ auricular contraction is similarly portrayed by auricular and

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† In all the figures, experimental and clinical, the leads have been from right upper and left lower extremities.

‡ I use the term "ectopic contraction" to designate contractions arising in any portion of the musculature other than that lying in the neighbourhood of the superior cavo-auricular junction, and include contractions of the whole heart, or of auricle or ventricle alone where the contraction is not propagated from one chamber to the other.

It is essential that it should be observed that the definition covers not only the premature beat hitherto frequently designated as extrasystole, but is also intended to include contractions of a distinct nature; for example, the beats of an ideoventricular rhythm (the true ventricular

ventricular electric complexes, and it is to the characters and variations which obtain in these complexes, as they are found associated with pathological beats arising in the auricle, that our attention will be especially directed.

THE AURICULAR COMPLEX OF THE ARTIFICIALLY EXCITED AURICULAR CONTRACTION. THE PACE-MAKER OF THE HEART.

Method.—In studying the electric changes produced in the heart as a result of its contraction in response to artificial excitation, it is very essential that the muscle should be damaged in the slightest possible degree, and it is necessary that when the curves are taken the heart should lie in the chest with its relationships to the chest wall undisturbed.

To produce artificial contractions, originating at definitely known points in the musculature of the auricle, necessitates the opening of the thorax, and the procedure adopted during the present experiments was as follows.

Dogs were rendered insensitive with morphia and paraldehyde, and a sufficiency of ether was employed to procure a complete or deep surgical anæsthesia. The thorax was opened by a flap method, either in the middle line or by making a window in the ribs, while the lungs were ventilated artificially. Small slits were made in the pericardium over the desired points, and insulated electrodes were attached to the auricle in definite regions. In the earlier experiments the electrodes were sewn into the epicardium, but in the majority of observations special electrodes terminating in minute trout hooks were employed. The fish hooks damage the musculature to the most trifling extent. In any given experiment no more than two, three, or four points of stimulation were chosen, and one of these invariably lay, as a control, at the junction of the superior vena cava with the auricle or in this neighbourhood. The remaining electrodes were attached to one or more of the following areas: the inferior vena cava, the pulmonary veins, the tips of the right or left auricular appendix, the base of the right

rhythm which is found when auricle and ventricle are completely dissociated). Two very different types of impulse formation are met with in the heart, a normal or physiological type, characterised by its long intervals of impulse formation, and a pathological type, characterised by the brevity of these intervals. The heart contractions, therefore, fall naturally into four categories:—

1. Contractions dependent upon a physiological type of impulse formation, and arising at the site of the pace-maker; the normal heart beat.
2. Contractions dependent upon a pathological type of impulse formation, and arising at the site of the pace-maker; the so-called "sinus extrasystole."
3. Contractions dependent upon a physiological type of impulse formation, and arising in an area of the musculature removed from the site of the pace-maker; for example, the "ideoventricular" contractions of the ventricle.
4. Contractions dependent upon a pathological type of impulse formation, and arising in areas of the musculature removed from the pace-maker; for example, the so-called "ventricular extrasystole."

appendix, or a point upon the internal surface of the right auricle. For the last-named observations a special electrode was devised. It consisted of a small glass tube carrying covered wires and having at its lower extremity two small exposed fish hooks in conduction with the wires. By employing this form of electrode certain points, subsequently ascertainable, could be reached, by way of the internal jugular vein and superior vena cava, upon the internal surface of the right auricle. In the successful experiments the electrodes were discovered attached to the mouths of the inferior vena cava and coronary sinus. With the electrodes in place the thorax was closed, all parts being brought into as natural a position as possible. All traces of air were removed from the pleural cavities and natural respiration was restored.

The electrocardiograms were obtained with Edelmann's large pattern of the string galvanometer of Einthoven; the leads were from the right forepaw or right shoulder, and from the left hind-paw or groin. These leads were chosen because they presented a close parallel to those employed for routine clinical work.

The artificial contractions were excited by make or break induction shocks, usually signalled, and either single or successive. The successive excitations have been found to be the more convenient, but similar results are obtained by one or other method. In using regular and successive stimuli, an interrupter, of which the rate could be varied at will, has been employed, and a rate of rhythmic excitation, sufficient to outpace the normal heart rhythm* but insufficient to induce fibrillation, has been utilised. By these means a tachycardia may be excited from any chosen spot upon the auricular walls, with the heart beating under natural conditions, and the electric curve which such a rhythm gives rise to may be compared with that of the normal rhythm which reappears at the cessation of stimulation. The strength of stimulus chosen was the minimally efficient one, whereby the complication of the curves by the record of the stimulus discharge itself has been avoided in most instances. The desired restoration of natural breathing, and the need of obtaining a heart rhythm, not appreciably accelerated, prohibited vagal section.

The accompanying figures are examples of curves obtained by the methods described.

In previous communications, based in part upon clinical, in part upon experimental findings, I have repeatedly urged the recognition of the fundamental view that the electric curve is an important indication of the direction of the path pursued by the contraction wave in the musculature and that

* I have employed very varying rates of stimulation in single animals, but in the accompanying curves give examples of artificial tachycardias only slightly faster than the normal rhythm. And I do so for these reasons; while the results obtained are the same, in so far as they affect my conclusions, with the faster rates the variation P tends to fall back upon the preceding T, and is consequently obscured. Furthermore, the comparison of normal and excited rhythms is the more exact, the more closely the rates of the respective rhythms correspond.

as a consequence it is an equally important guide to the birth-place of the impulse leading to such contraction. The conclusion that an abnormal auricular complex is significant in evidencing an abnormal or ectopic site of impulse generation is substantiated by the direct or experimental test.

The auricular complex which results upon excitation of an area in the neighbourhood of the junction of superior vena cava and right auricle.

In all, there are fourteen observations upon thirteen animals. The complete series of observations are shown in the opening columns of the accompanying figure (Fig. 1). This figure has been constructed by accurately tracing the complexes of the auricular representatives in the electric curves. The normal curves are given in the first vertical column (N), and the succeeding vertical columns include the curves obtained as a result of artificial excitations. The second column, with which we are at present concerned (S.V.C.), contains the complexes obtained upon stimulation of the superior cavo-auricular junction. Actual records are to be found in Figs. 4, 5, 6, 7, 13 and 15.

In all instances, stimulation of the superior cavo-auricular junction has yielded complexes bearing a striking resemblance to the normal complex. The duplication is usually absolute (Fig. 4 I), or almost absolute (Fig. 6 I). Where slight variation has occurred between normal complex and artificially excited complex, it has been, generally speaking, no greater than the variation met with in the outline of the normal complex in the same animal, as an accompaniment of respiration or some other and indeterminate cause*. But such variation is, as can be seen in the diagram, inappreciable in degree. The actual points of stimulation are shown in Fig. 2, an outline drawing of the base of the heart from which aorta and pulmonary artery have been removed. A single point has been utilised at the junction in all experiments

* A variation in the normal curve is shown in Fig. 5 III. The difficulty experienced in such instances is the choice of the complex for comparison with the artificially excited beat. Fortunately it is of rare occurrence. The accompanying figure illustrates the sole example met with during the present investigation.

Fig. 1. A diagram showing the electric complexes of the auricular systoles in a series of thirteen experiments (natural size). The number of the experiment is indicated to the left. The point from which the auricular systole was propagated is indicated above. Each curve has been traced from the original photograph. Where slight variations in type have been present from beat to beat, that type has been chosen which is of most frequent occurrence. N = normal complex. S.V.C. = that obtained from superior vena caval areas (*h* the upper point, and *l* the lower point of excitation). I.V.C. = from inferior vena caval area, an asterisk is placed against curves obtained by internal stimulation. P.V. = from area of pulmonary veins. C.S. = from coronary sinus, internal stimulation. A.B. = from base of auricular appendix. R.A. = from right and L.A. = from left auricular appendix. The curves of the first six experiments were taken at a comparatively low speed, and the P-R intervals are therefore omitted. They are marked in seconds in the horizontal columns 7-13.

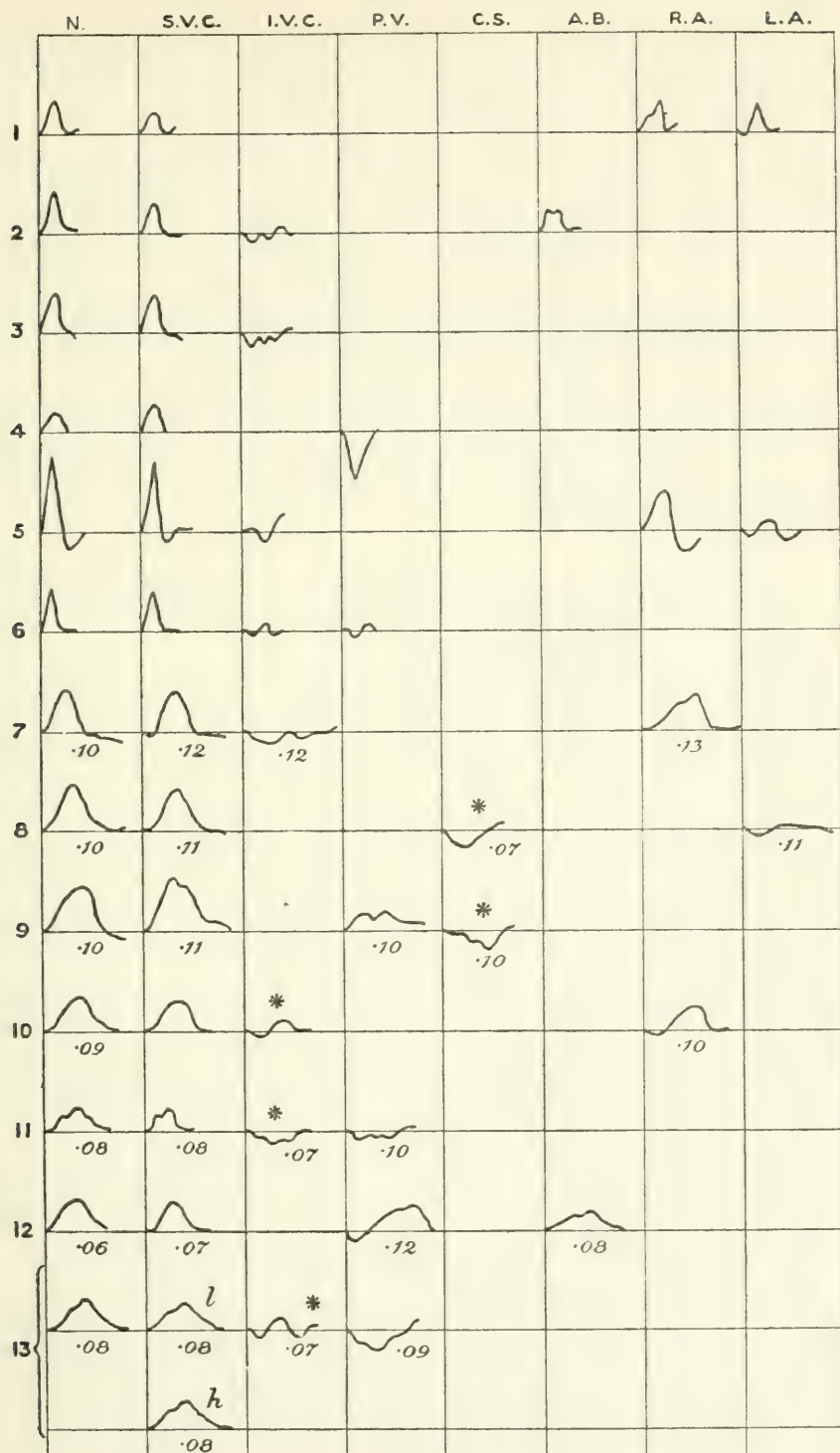


Fig. 1.

but one (No. 13). In this instance two points were chosen upon the *sulcus terminalis* and a comparison between the two instituted*. The curves obtained are bracketed together in the diagram (Fig. 1).

It will be seen that the area from which artificially excited auricular complexes, similar to the normal, are obtainable, lies in and around the junction, and that a closer differentiation by means of the method employed is impracticable. Comparing normal and artificially excited curves, the differences noticed from animal to animal, where the excitation points are separated by $\frac{1}{2}$ to 1 cm., are very slight, and it cannot be said that any particular point on the junction line yields curves approximating most closely to the normal curve. The same statement applies to two separate points on the junction line, in one and the same animal.

The variations which are met with amongst the complexes obtained artificially from animal to animal from the junctional area are no greater than and are of similar character to the variations met with in the normal complexes of the same series.

The auricular complex which results upon excitation of an area in the neighbourhood of the inlet of the inferior vena cava.

There are eight observations in all.

We have seen that there is a variation in the complex yielded by excitation of the base of the superior vena cava, and that this runs hand in hand with the variations of the normal curves. Similar variations are met with in the curves resulting upon stimulation of the inferior vena cava (Fig. 1, column I.V.C., and Figs. 5 II and 15). The points of stimulation upon the superficies of the heart are shown in Fig. 3. They lie at the caudal and right portions of the base of this great vein, and largely over the termination of the coronary sinus. The excitation points upon the internal surface of the auricle are marked with an asterisk in Fig. 1. In experiment 11 the upper part of the vein, well inside the mouth, was the site of stimulation. In experiments 10 and 13 the upper or cephalic lip of the mouth of the vein. The mouth of the vein in the dog when viewed from within is very capacious. The attachment of the electrodes to its cephalic lip consequently places the point of stimulation much nearer to the superior vena cava than the points of stimulation upon the superficies (the points seen in Fig. 3).

In this series of curves there is very considerable variation in the type of complex shown, and no particular type can be regarded as specific. Nevertheless certain general statements may be made in regard to the curves.

* In giving diagrams of the points stimulated it is necessary to state that these points are approximately placed, and approximately only. The variation from animal to animal in the general conformation of the auricle has to be remembered, in particular the variation in the arrangement of the pulmonary veins. I have been guided in inserting them by the most fixed points, paying especial attention to the relationships to the S.V.C., the I.V.C., the *sulcus terminalis*, and the auriculo-ventricular groove.

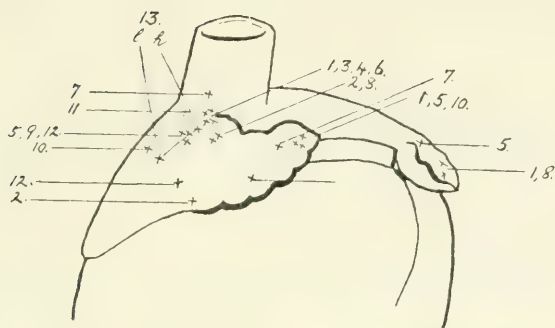


Fig. 2.

Fig. 2. An outline of the base of a dog's heart, to show the points of stimulation in the experiments. Seen from in front, with the aorta and pulmonary artery removed.

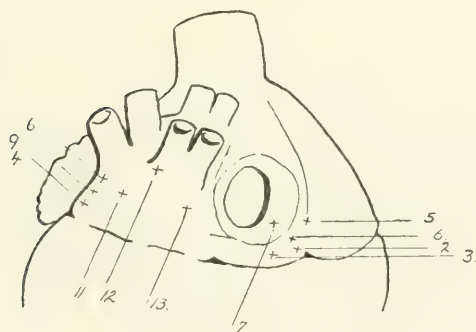


Fig. 3.

Fig. 3. An outline of the base of a dog's heart, to show the points of stimulation in the experiments. Seen from behind.

The complexes are always clearly distinguishable from the normal complexes. They are constituted by several distinct phases. As a rule there is an approximately equal distribution of upwardly directed (or base negative) and downwardly directed (apex negative) portions. The curves tend towards the isoelectric position. They commence with a downwardly directed (or apex negative) phase.

The auricular complex which results upon excitation of an area in the neighbourhood of the inlet of the pulmonary veins.

There are six observations (Fig. 1, column P.V., and Fig. 6 III).

The complex obtained from the neighbourhood of the pulmonary veins is more variable than that from the region of the inferior vena cava, the area is larger, and the general statements which may be made are therefore less numerous. The type of complex is always clearly distinguished from the normal complex. In five of the observations it commenced with a downwardly directed (or apex negative) phase. In one instance a very accentuated downward displacement was apparent (Fig. 1, experiment 4), and the point stimulated happened to be that which, in the series, was most removed from the S.V.C.. In another instance the complex was prominently in the upward direction (Fig. 1, experiment 12), and the point of stimulation was the most approximate to the S.V.C.. (The extent of upward or downwardly directed phases does not run exactly hand-in-hand with the distance from S.V.C.).

The auricular complex which results upon excitation of the mouth of the coronary sinus.

There are two observations (Fig. 1, column C.S., and Figs. 4 II and 6 II). The hooks of the internal electrode were found attached in each instance to the upper or cephalic lip of the coronary sinus. The curves are in the main downward displacements, and in one case there is a very appreciable shortening of the P-R interval as compared to the normal (Fig. 4). The shortening is from 0.10 to 0.07 sec.. This point of stimulation represents the nearest approach to the node of Tawara obtaining in the present series of experiments.

The auricular complex which results upon excitation of the base of the right auricular appendix.

There are two observations (Fig. 1, column A.B.).

The curves yielded are entirely base negative in direction, but less extensive than the normal curves, and are clearly distinguishable from

them. In type they approach more nearly to those obtained from the superior cavo-auricular area than do any of the curves hitherto considered.

The complex resulting upon excitation of the tip of the right appendix.

There are four observations (Fig. 1, column R.A., and Fig. 5 I).

The curves are not dissimilar to those obtained from the superior cavo-auricular junction, but never duplicate them. The base-negative amplitude is less extensive, the rise is less abrupt, and there is a tendency towards the appearance of a distinct notch on the upstroke.

The complex obtained upon excitation of the left appendix.

There are three observations (Fig. 1, column L.A., and Fig. 4 III). The curves vary considerably. They are always quite dissimilar to the normal complexes. They have commenced with a brief or prolonged downward (apex negative) displacement.

GENERAL FINDINGS.

The observations, from a description of which we now proceed, permit us to formulate certain general statements.

A contraction of the auricle, excited artificially in the neighbourhood of the base or inlet of the superior vena cava, invariably yields an auricular electric complex identical with or closely resembling the auricular complex of the normal heart beat. No other area of the auricular musculature, when stimulated, propagates a contraction which yields an electric curve of the same type, but it is noteworthy that in its general conformity the complex considered approaches the normal type most nearly according as the point excited approaches the superior vena cava. The deduction is clear, while it is believed that, *cæteris paribus*, the electric curve is distinctive of the course pursued by the contraction wave, and, therefore, that it indicates the point at which such wave of contraction starts. We have curves propagated from a large series of points under review, and of these a certain number show a distinctive feature, namely a close resemblance to the natural curves obtained from the same animals. The shape of the auricular complex accompanying heart beats artificially provoked and starting in the area of the superior cavo-auricular junction, provides convincing evidence of the proximity of this junction and the pace-maker of the heart. A more accurate localisation by the means employed is impracticable as we have seen, but the

observations narrow the field of enquiry to a comparatively small area in the immediate neighbourhood of Keith and Flack's node*.

The second general conclusion of importance which may be drawn from the experiments concerns the identification of spontaneous beats arising in areas of the auricular musculature removed from the pace-maker. For, both in experiment and in clinical cases, spontaneous auricular systoles are not infrequently observed, which are represented in the electric curves by outlines distinct from the outlines of the normal beats. In such instances it may be asserted that such beats have arisen ectopically. Furthermore, the more prominent the upwardly directed (or base negative) phases of such ectopic curves, and the closer the resemblance borne to the normal type, the nearer is the extraneous point of impulse formation to the pace-maker. A curve which commences with a downwardly directed (apex negative) phase and is continued in an upward (or base negative) direction arises in all probability from the central zone of auricular tissue (for example, from the regions of the mouths of the inferior vena cava and pulmonary veins). A curve composed of phases falling entirely in the downward direction may similarly be attributed to the lower zones of the musculature (for example, the lowest part of the septum, where lie the mouth of the coronary sinus and the node of Tawara)†.

THE AURICULAR COMPLEX OF THE ABNORMAL AURICULAR CONTRACTIONS AS THEY ARE MET WITH IN CLINICAL CASES.

The observations have been made upon patients in whom single premature beats, or successive beats of a similar nature (paroxysms of tachycardia) have been frequent. In each case the relative positions of the auricular and ventricular contractions in the abnormal heart cycles have been fully confirmed by means of polygraph records. From a number of such patients, a few cases are chosen for purposes of illustration and the clinical histories and conditions of these have been already published.

Where an otherwise regular rhythm is disturbed by premature or by successive and abnormal beats arising in the auricle, the auricular complex presents definite characteristics. In the majority of patients it can be

* Another galvanometric method of localising the pace-maker may be employed. By leading off from the auricle itself, it may be ascertained which point of its musculature first demonstrates negativity, for negativity represents activity. Some preliminary observations have been undertaken from this point of view, and have been referred to in another place. It was found in two experiments that the neighbourhood of the superior vena cava first becomes negative during the progress of the electric changes accompanying the auricular systole. But at this stage of the observations I heard through Dr. Koch of Dr. Wybauw's observations, and understanding from Dr. Wybauw himself that they were arriving at completion, this line of investigation was not pursued.

† A curve, completely apex negative in direction, has also been obtained from the inferior cava, and from the neighbourhood of the pulmonary veins at a point far removed from the S.V.C..

shown that the complex of the abnormal beats is constant in the same patient from beat to beat or from day to day and month to month. The focus of disturbance in the auricular musculature is, therefore, a restricted one. In only one definite instance have beats been observed, which arose in several auricular foci. (Electrocardiograms from this case are shown in Figs. 9 and 11; the case is also the basis of a separate communication by Dr. Marris.)

From case to case the auricular complexes show marked variation. Reference may be made to the figures which are described in the ensuing paragraphs.

a). In Fig. 8 a short strip of electrocardiographic and radial curve is shown, from a patient, the full details of whose case have been recorded in the last number of this *Journal*. Two premature beats arising in the auricle are present. In each instance the premature auricular contraction coincides with the preceding ventricular systole, and a large variation consisting of the superimposed P and T variations results. I have many curves from the same case and in some of these P falls a little later in relationship to T; the component parts of the composite variation are more clearly differentiated in these instances. In the illustration given it will be found that the height of the normal P variations when added to corresponding T variations yields a sum which is equivalent to the height of the composite variation.

The peaks of P and T have fallen precisely together. We have to deal, therefore, with an auricular complex, in the instance of the premature beat, which is of equal height with the normal P variation of which the displacement is entirely upward in direction*.

b). Fig. 9 is an example of simultaneous electric and radial curves from a case of paroxysmal tachycardia, described in the last number of this *Journal*. The paroxysms were shown to have their origin in the auricle and it was considered probable that they arose from the lowest level of the musculature. It will be observed that accompanying the early beats of the figure the P variations are normal in form. During the paroxysmal stage the P variations are inverted and entirely downward (or apex negative) in direction. The P-R intervals are also shortened during the paroxysmal stage. The nearest approach to this type of complex, given by the experimental observations described in this paper, is that shown as proceeding from the coronary sinus in Fig. 4 II.

c). In an earlier paper a case of paroxysmal tachycardia was described and it was shown that the paroxysms themselves and the premature beats disturbing the slow periods were auricular in origin. A new figure is published from this case (Fig. 10). In this figure a single premature beat is shown in each of the separate tracings. In every instance the premature P variation falls with the preceding T variation and deforms it. As in Fig. 8 the two variations, the abnormal P and the abnormal T, are algebraically superimposed. The composite curve may be resolved by subtracting the

* This figure shows a distinct prolongation of the premature P-R interval.

normal T. It is obvious that the type of abnormal P variation consists of a small variation in the downward direction, but that in the main it is isoelectric, for the T upon which it falls is notched in its opening phase. Fig. 12 is a curve from this case in which with the occurrence of a paroxysm of abnormal beats each alternate auricular impulse is blocked on its way to the ventricle. As a result the alternate P variations fall clear of the preceding ventricular complexes and the shape is clearly shown*. A small downwardly directed peak is succeeded by a long isoelectric period.

d). An example of a purely isoelectric P is shown in Fig. 11, and was obtained from the same case as the curve shown in Fig. 9.

The premature beats are known to be auricular in origin, for no other form of interruption of the normal rhythm has been evidenced by venous curves taken from this case, and also because all such beats show an absence of a complete compensatory pause. A purely isoelectric representative of the auricular systole has not occurred in the experimental observations.

The examples which have been given (*a*, *b*, *c*, and *d*) should suffice to illustrate the three main types of auricular electric variation as they are met with in clinical studies. They group themselves as follows:—

a). A full base negative variation.

b). A full apex negative variation with or without shortening of the P-R interval.

c and *d*). An auricular representative which is isoelectric (*d*), or which tends towards this position, with a bias somewhat towards the base or towards the apex negative condition (*c*).

They are recognised as significant of premature beats arising:—

a). In the upper regions of the auricle; that is to say, in the neighbourhood of the pace-maker.

b). In the lowest region of the auricular musculature; that is to say, in the neighbourhood of the node of Tawara; or where there is no shortening of the P-R interval, possibly from the region of the pulmonary veins.

c and *d*). In the middle region of the auricle; that is to say, in the neighbourhood of the inferior cava or pulmonary veins, or left appendix, with a bias towards the superior vena cava on the one hand or the lower levels of the auricle on the other hand.

An absolute localisation is of necessity impossible at the present stage of the enquiry; nevertheless localisation is obviously possible within certain limits.

* Periods of this mechanism were graphically recorded by means of the polygraph, and were published in an earlier paper. They were interpreted as periods of "interpolated auricular extrasystoles." In the light of the electric curves this explanation can no longer be held.

On the other hand the most important conclusion to which the attempt at localisation leads is of a perfectly precise nature. It is a conclusion which has been previously arrived at from theoretical considerations and other data. We know positively that not only single *ectopic* beats but that successive ectopic beats, constituting a rhythm, are to be found, and not uncommonly, in clinical cases. The comparison of clinical and experimental curves proves beyond question the generation of certain paroxysms of tachycardia in areas of the auricular musculature removed from the pacemaker. These cases are illustrations of a temporary dislocation of the rhythm of the heart from the normal pace-making area at the base of the superior vena cava, to points in the remaining auricular musculature.

THE VENTRICULAR COMPLEX ACCOMPANYING THE RESPONSE TO THE ARTIFICIALLY EXCITED AURICULAR CONTRACTION AND ACCOMPANYING THE RESPONSE TO THE ABNORMAL AURICULAR CONTRACTIONS AS THEY ARE MET WITH IN CLINICAL CASES.

When an impulse starting a ventricular contraction originates in the supraventricular portions of the heart, we have reason to believe that the contraction of the ventricle is started in those portions of the ventricular walls which are most directly united to the auricular musculature. We should be led to anticipate that all such ventricular contractions would yield a specific and normal type of ventricular complex. Within certain limits this rule holds good (Fig. 8). But at the same time there are numerous exceptions to it and the conditions giving rise to them require closer examination. I do not propose to give a full account of the changes or combination of changes encountered in the ventricular complex, but choose those varieties which stand out most conspicuously.

The commonest type of ventricular complex following an artificially excited auricular contraction in experiment, and the most frequent type in clinical cases where a normal heart rhythm is interrupted by premature or paroxysmal beats of auricular origin, is of the normal form and consists of R and T (or R, S and T or Q, R, S and T) variations, which approximately duplicate the normal ventricular complex (see Figs. 4 and 8). In such curves the peak R usually tends to diminish in size according to the degree of prematurity of the contraction which originates it.

1). A notable change is seen in certain experimental instances. Clinically I have not as yet met with it. It consists in changes *chiefly* confined to an alteration in the extent or direction of the phase T, and is illustrated in Figs. 13 and 14. The normal complexes of these figures are characterised by well-marked and upright R and T phases and a small variation S. The premature beats, two of which appear in Fig. 13, and one of which appears in Fig. 14, show clearly marked differences. Accompanying the earliest

beats the T variation is completely inverted (the first premature beat of Fig. 13). Beats which are not quite so premature show both an upwardly and a downwardly directed peak (the premature beat of Fig. 14). While still later abnormal beats show a simple decrease in the amplitude of T (the second premature beat of Fig. 13). The phenomenon is extended to the beats which succeed the premature beats, for in these the amplitude of T is exaggerated. These changes may occur with or without an associated change in the amplitude of R.

2). The second change of importance which is met with is a notable alteration in the amplitude of R, but the alteration referred to is usually accompanied by an inversion of or increase in the depth of T (the latter is present, where T is originally inverted). At the same time the depression S disappears. In Fig. 13 there is a very slight but definite increase in the amplitude of the R (of the first premature beat), and the phase S, which though small in the normal beats is quite distinct, is absent in the premature complex. More pronounced instances of this phenomenon are shown in Fig. 7. In Fig. 7 II and III single artificially excited beats are shown. There is one in Fig. 7 III and there are two in Fig. 7 II. If the three beats are compared it will be seen that where the excitation falls late in diastole the resultant ventricular complex is a duplicate of the normal (Fig. 7 III), while, as it falls earlier and earlier in the diastole of the preceding heart cycle, R rapidly increases in amplitude and T tends to become more depressed. In this animal the T of the normal beat was inverted, but the same changes are frequently seen where T is originally upright; in such instances T may become inverted. In experimental auricular tachycardias precisely similar changes are noticed, and they vary in degree, according to the rate of the rhythm provoked. This is clearly shown in Fig. 7 I. As an accompaniment of the faster tachycardia, the amplitude of R is greater, and T is slightly more depressed (compare Fig. 6 III, from the same animal).

Similar events are seen in clinical cases. It is usual to find that the peaks R of auricular tachycardias are taller than those of the normal beats in the same patient. Single premature beats, showing parallel changes, are also met with clinically. An example is shown in Fig. 11. Two ectopic beats are depicted which have arisen in the auricle. The representative of the auricular systole is absent, the auricular curve is in fact isoelectric. The peaks R are greatly exaggerated and T is in each case inverted. The importance of the recognition of this type of change in the ventricular complex of premature or successive abnormal beats springing from the auricle, lies in the resemblance of the type to the complex accompanying an ectopic beat arising from the musculature of the basal and right portions of the ventricle.

I have described two varieties of change (1 and 2), in one of which with the early abnormal beat the *chief* alteration is in the form of a depression or inversion of T, in the other of which the *chief* alteration is an increased amplitude of R. But it should be clearly understood that while the two

phenomena are certainly largely independent of each other, yet they are usually found together, one or other predominating.

3). Another important change seems to stand by itself. It is illustrated in Figs. 10 and 15, and is perhaps the most remarkable of all. It has been met with in three experimental cases and in two clinical cases.

In Fig. 15 are four curves, A, B, C, and D, from a single animal. The point of excitation in A and C was the superior vena cava; and in B and D the inferior vena cava. The differences in the premature P variations according to the site of stimulation are characteristic. Now in A and B excitation fell at an early stage in the diastole, while in C and D it fell later. The change in the ventricular complex which is shown in A and B has never been encountered except when the interval between premature beat and the preceding heart contraction has been short, and the type tends to exaggerate as the interval is shorter. The chief change is a striking increase in the amplitude of S and an increase in the prominence of T. In each of the three experiments the same facts were observed. The increase of S is not associated with its original prominence in the normal beat, for in the remaining animals S was small in the normal complexes. But an examination of all the curves shows that its great amplitude in the figured instance is in part attributable to its original prominence. It is entirely independent of the site of stimulation, for it has been produced from the inferior and superior vena cava (Fig. 15 A and B) and also from the pulmonary veins. (The independence of the changes, recorded in previous paragraphs, of the site of stimulation is equally true.)

A point to which attention is specially directed, and which will be discussed at a later stage, is the increase of the P-R interval accompanying the premature beats in this figure.

In a previous communication three types of ventricular complex accompanying premature auricular beats were described in curves taken from a single patient.

For convenience of description they were designated types I, II, and III. Our attention will be confined for the present to the types I and III, for of type II there is neither an experimental duplicate nor is there further evidence in regard to it.

In Fig. 10 five strips of curve are given, and they were taken, from the patient referred to, at one sitting. Each includes a single ectopic beat. Following the onset of the second rhythmic ventricular complex in each curve at a time distance of 0.2 sec. is the representative of the ectopic auricular contraction. It manifests itself, as previously noticed, by notching the preceding T in the downward direction. This P variation is followed in each instance by a ventricular complex, and in 10 A it conforms to what I originally designated type I, while in Fig. 10 E it is of the form of type III. The remaining curves are arranged in their natural order. The P-R intervals of the several abnormal beats decrease as they are traced from above

downwards, namely, from 0.26 to 0.14 sec.* The parallel to the experimental curves shown in Fig. 14 is remarkable, and the underlying mechanism is probably of a similar nature. The ventricular contraction which is early has the S phase exaggerated, and in one example, Fig. 10 D, T is also exaggerated. The transition of the types in Fig. 10 is not perfect, for while S increases progressively, the amplitude of R decreases only as far as Fig. 10 D, and in 10 E shows an increase of its excursion.

It is noteworthy that in the clinical instance there are marked changes in the conduction intervals, and these in themselves account for the varying length of pause existing between premature ventricular beat and its predecessor. Changes in conduction were also described in connection with Fig. 14, but there is this difference: although the earlier ventricular beat in both clinical and experimental instance is accompanied by the exaggerated S phase, yet the P-R interval in the clinical instance is shorter when the abnormal beat is earliest and the reverse is the case in the experimental example.

The observations upon the changes in the conduction intervals lead up to the final remarks which I propose to offer upon the variations obtaining in the ventricular complexes accompanying abnormal contractions arising in the auricle, for I shall content myself at the present time by placing the main facts on record. At the same time I desire to advance a view as to the causation of these and other variations, but do so in the most tentative fashion. The argument centres around the following facts. The chief changes are met with in the earliest of the premature beats, and such beats are frequently accompanied by evidences of deficient conduction in the musculature. In studying the ventricular complexes of beats arising ectopically in the ventricle itself, I have been impressed by the absence or relative absence of change in the conformity of the curves according to the instant in diastole at which they occur or are excited. In this respect they offer a marked contrast to the ventricular complexes of ectopic beats arising in the auricle. Now when the ventricle is excited by the application of a small stimulating electrode to its walls, the contraction is propagated *from a single point*, while in the case of a ventricular beat originating in a supra-ventricular impulse, the impulse is received on right and left side and the contraction is initiated in at least two areas, the arborisations of the right and left branches of the bundle. The suggestion offered is one which is parallel to that put forward by Einthoven in explanation of the variations which occur in the normal electrocardiogram from man to man or animal to animal. The distribution of the impulse awakening the ventricular response may vary. It is possible that the variations in the ventricular complex associated with a premature auricular contraction are similarly

* In the original account I stated that the differences in the type of ventricular complex could not be accounted for by differences in time relationships. When the paper was written I had but few examples of type I, and sufficient observations could not be made upon it. The statement applied more particularly to types II and III. The origin of type II is still as obscure as before.

dependent upon a variation in the impulse distribution from beat to beat. The view is supported by the observation that certain of the most highly atypical complexes are frequently accompanied by obvious changes in the conduction intervals.

Supposing that such changes are located in the junctional tissues, the A-V bundle and its arborisation, may it not be that there is a greater defect in one part of the system than in another and that the defect may vary quantitatively from time to time, and that as a consequence the impulse descending from the auricle first reaches one part of the musculature of the ventricle when the contraction is early, and another portion of the musculature when the contraction is later? A complex of the type shown in Fig. 11, and one which resembles that obtained on provoking a contraction from the basal and right portions of the ventricle, would receive explanation along these lines by supposing that at the time of the propagation of the impulse to the ventricle the function of the right branch of the bundle was further restored than that of the left branch. The impulse under these circumstances would travel more rapidly to the right ventricle, and awakening a response in it, the whole ventricle (right and left) might be thrown into contraction as a result of the distribution of the impulse to this area alone. If such were the conditions, a ventricular complex, simulating that obtained on artificial excitation of the basal and right portion of the ventricle, would certainly be anticipated.

CONCLUSIONS.

1. The form of the auricular electric complex accompanying an auricular contraction is intimately connected with the focus in which such a contraction is generated.

2. No two areas of the auricular musculature give rise to contractions represented by similar complexes. The areas from which distinct complexes are obtainable are relatively small.

3. The auricular complex of an excited auricular contraction may be normal in form, diminished, or partially or completely inverted. The auricular tissue may be arbitrarily divided into three zones, an upper, a lower, and a central. The upper zone will yield complexes of a chiefly upright form, the lower zone those of a chiefly inverted form, while the central zone will yield curves which approach to an isoelectric state.

4. The normal auricular complex is most closely simulated by beats excited from the neighbourhood of Keith and Flack's node. The pacemaker of the heart is therefore situated in the neighbourhood of the superior cavo-auricular junction.

5. The ventricular complex accompanying premature beats arising in the auricle is subject to considerable variation. The variations are independent of the site of impulse production in the auricle, but are largely though not entirely dependent upon the instant at which the ventricle contracts in relationship to the preceding systole.

6. Experimental premature contractions and tachycardias provoked in the auricle show many features in common with premature auricular contractions and spontaneous tachycardias as they are met with clinically. The points of origin of the abnormal clinical contractions may be localised within certain limits.

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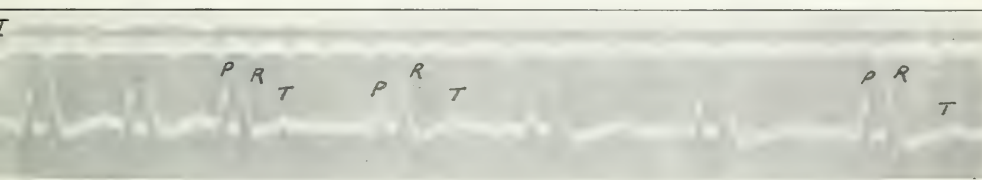
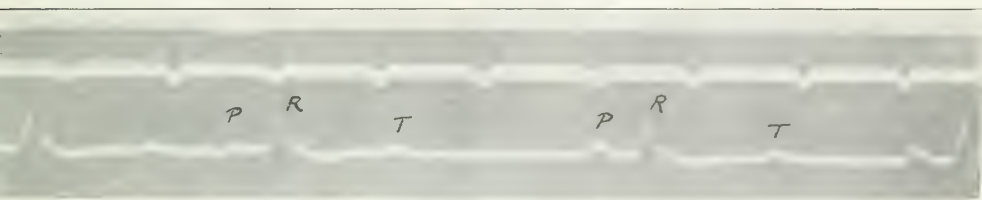
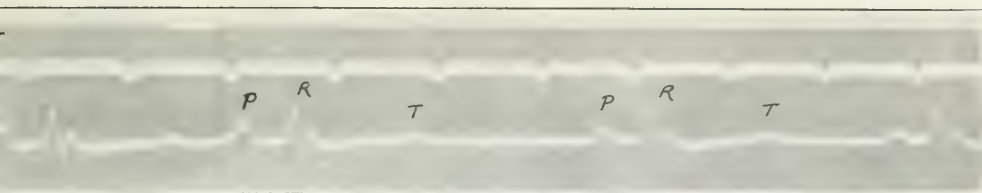


FIG. 5.

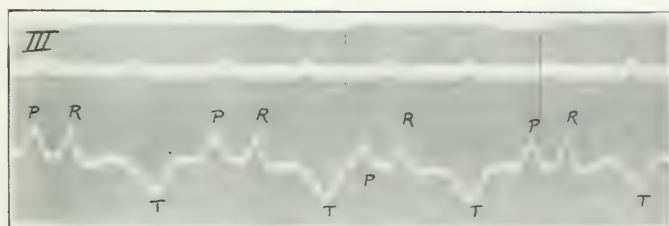
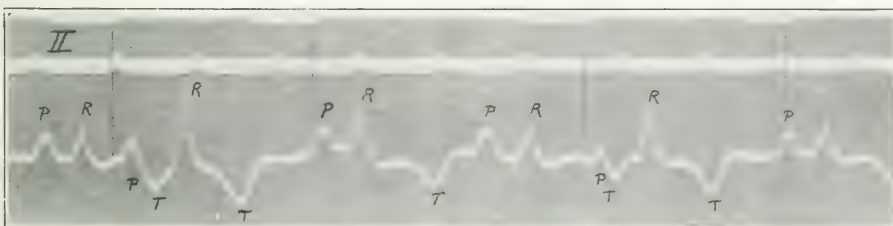
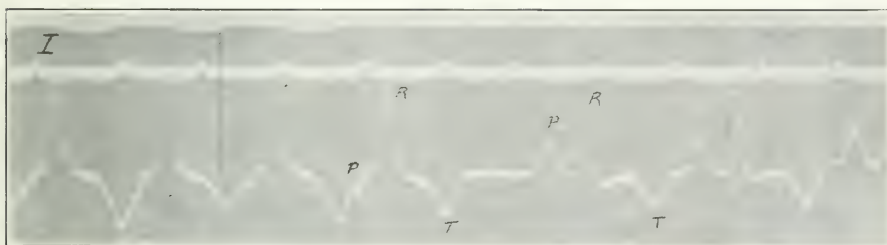
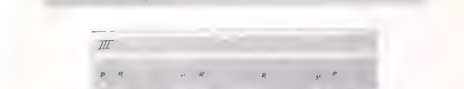
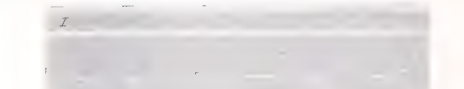
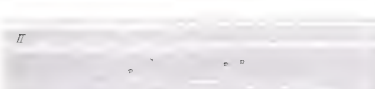


FIG. 7.



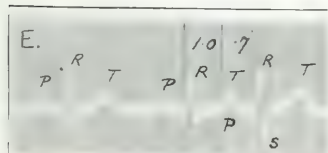
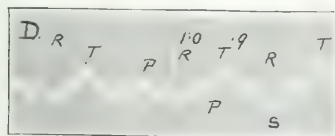
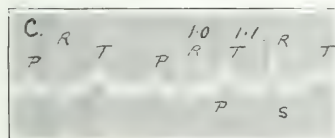
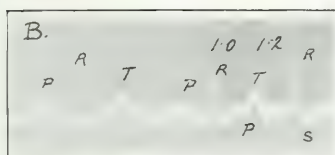
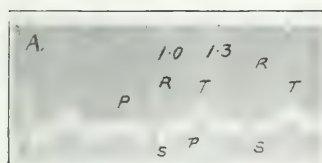
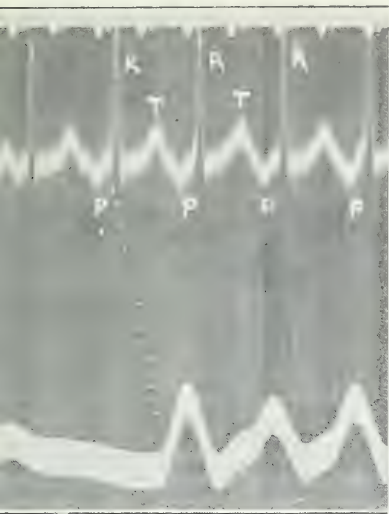
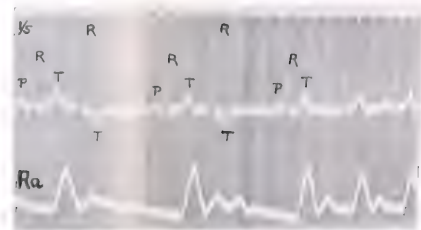
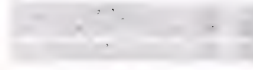
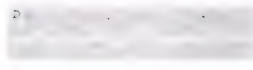
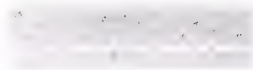
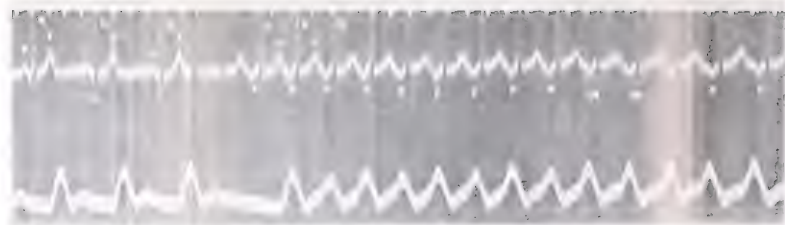


FIG 10.



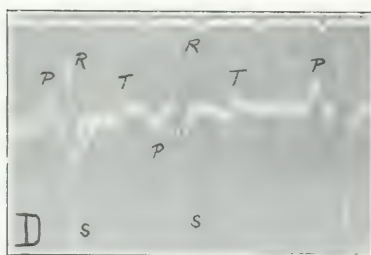
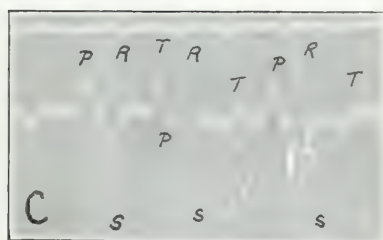
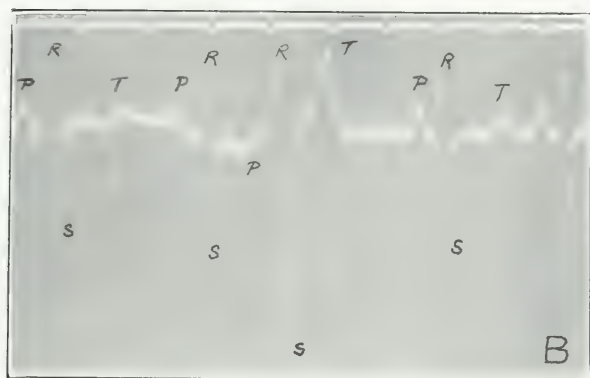
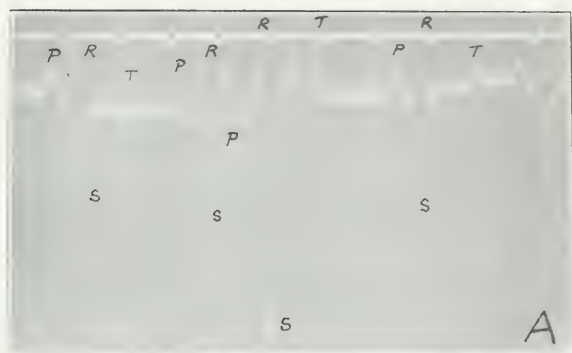
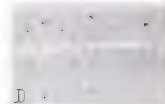
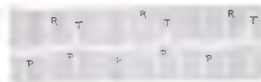


FIG. 15



AURICULO-VENTRICULAR HEART-BLOCK AS A RESULT OF ASPHYXIA.*

BY THOMAS LEWIS AND G. C. MATHISON.

(*From University College Hospital Medical School.*)

IN an article upon the mammalian spinal animal, recently published, Sherrington² speaks of a sudden diminution of heart rate in asphyxia. He writes as follows: "From a frequency of 300 per minute it now absolutely abruptly drops to 140 to 150 per minute," and again, he says, "This sudden check of the heart's rate is not due to vagus action, for it occurs still quite typically after administration of atropin has set aside all cardiac inhibition obtainable by stimulation of the vagus trunk in the neck."

This year Roaf and Sherrington¹, writing upon the same subject, state that "At a certain stage of asphyxia there ensues, as shown in the previous paper, an abrupt reduction in the frequency of the ventricular beat, not due to vagus inhibition. It is in fact due to heart-block."

In view of the fact that neither Sherrington nor Roaf and Sherrington have brought forward evidence of the occurrence of heart-block during asphyxia, and knowing that an apparent halving of ventricular rate may occur in the mammalian heart, in the absence of heart-block, and in the absence of vagal inhibition, we considered it advisable to investigate the matter more closely. Using Edelmann's large pattern of Einthoven's string galvanometer, we have taken electrocardiograms from the right fore limb and left hind limb of cats.

The heart contractions have been recorded in the decapitated or spinal cat, and in the decerebrate animal under artificial respiration. They have also been recorded in the intact and curarised animal, with the vagi intact and with the vagi divided. Further, they have been registered in the spinal animal under doses of atropine, sufficient to paralyse the vagus terminations, as tested by faradisation of this nerve in the neck. Our results, in so far as they are stated in this paper, have been uniform.

It was desirable that the records should be taken at a moderately fast rate for purposes of measurement, and as a continuous record of a complete asphyxial observation, from its start to its finish, was impossible at such speeds, we took sample tracings at intervals of about 30 sec.. These intervals, as stated in the accompanying table, are sometimes shorter and sometimes longer than 30 sec., for in watching the movements of the shadow

*An account of observations undertaken under the tenure of Beit Memorial Fellowships.

of the string, it is not difficult to appreciate certain changes in the mechanism of the heart-beat, and often with the onset of such a change we obtained an early or late tracing. The first table which is given is a fairly characteristic example of such an observation. It differs from the remaining experiments in the fact that the onset of heart-block is, as a rule, earlier than is here shown.

TABLE I. Cat 1. Obs. 4. Decapitated Cat. Artificial Ventilation. 1/100 gr. atropine sulphate.

Duration of Asphyxia in min. & sec.	Auricular Rate.	P-R Interval.	Ventricular Rate.	REMARKS.
0,0	124	·08	124	
0,30	125	·08—·09	125	
1,0	127	·07—·08	127	
2,0	127	·08	127	
2,15	127	·08	127	
2,30	161	·08—·10	161	
3,15	180	·08	180	
3,30	182	·08	182	Sl. variation of auricular rate.
4,0	161	·08	161	
4,15	142	·12—·13	142	Prolongation of P-R interval.
5,0	122	·12—·13	122	Sl. variation of auricular rate.
5,30	113	·12—·13	113	
5,45	107	·12—·13	107	
6,0	97	·14—·16	48·5	2 : 1 H.B. Sl. variation of auricular rate.
6,30	96	·16	48	
7,30	90	—	52	C. H. B.

With restoration of ventilation the heart rate quickened to the original rate, and the heart-block disappeared.

TABLE II. Cat 10. Obs. 4. Intact animal; artificial respiration; urethane and curare; vagi cut.

Duration of Asphyxia.	Auricular Rate.	P-R Interval.	Ventricular Rate.	REMARKS.
0,0	192	·10	192	
1,0	192	·10	192	
1,15	187	·10 +	187	
1,30	187	·10	187	
1,45	205	·10	205	T increasing
1,50	205	·12	205	T markedly exaggerated
2,30	150	·13	150	
3,0	130	·14—·15	130	
3,5	126	·15—·16	63	2 : 1 H.B.
4,15	105	—	67	C.H.B. One extrasystole.
4,40	101	—	59	C.H.B.
5,10	98	·18	49	2 : 1.
5,45	—	—	33	Auricle not recording.

The heart subsequently showed complete recovery, the P-R interval measuring ·08—·10 sec (cf. Fig. 4c.).

From left to right it indicates the duration of asphyxia, the rate of the auricle per minute, the P-R intervals in seconds, and the ventricular rate.

The second table is similarly arranged; the time relationships are more typical. It shows an exceptional occurrence, the break back of complete to 2 : 1 heart-block.*

Within two or three minutes of the onset of asphyxia the rate of the auricles and consequently that of the ventricles increases. At $1\frac{1}{2}$ to $4\frac{1}{4}$ minutes (usually early) a prolongation of the P-R interval occurs, and this is the first evidence of the subsequent fully developed heart-block. It is either accompanied or directly preceded by a retardation of the auricular rate, and the decrease may be considerable. Following upon this stage is a further and steady decrease of auricular rate, and it is associated with the appearance of other grades of heart-block, of which examples are published (Fig. 1). The prolongation of the P-R interval becomes exaggerated, and it may lengthen to double or treble the original measurement (the longest interval recorded has been 0.3 sec.). (The normal interval for cats is about 0.08 to 0.1 sec.). Within two minutes (usually less) of this evidence of diminished conductivity of impulse transmission from auricle to ventricle, auricular impulses fail to reach the ventricle. At first there may be an occasional dropped beat (Figs. 2 and 3), there may be dropped alternate beats (2 : 1 heart-block, Fig. 1 III). Where single beats are dropped a condition comparable to that which is found in clinical cases has been met with. The already lengthened P-R interval rapidly increases still further up to the point where the dropped beat is seen. This preliminary lengthening of the P-R interval is clearly shown in Figs. 2 and 3 and the intervals increase to such an extent that the auricular systoles (P) fall back upon the preceding ventricular systoles (R and T), so that the contraction is partially synchronous in the two chambers. The first P-R interval succeeding the failure of a ventricular response is invariably relatively short, a shortening which has been frequently pointed out in clinical cases and which is attributable to the long rest which precedes it.

Following upon the stage of prolonged P-R interval or upon a period of dropped beats, 2 : 1 heart-block manifests itself (Fig. 1 III). The auricular rate during this period is always markedly retarded (despite the section of the vagi, or the administration of atropine), and the P-R intervals retain their increased length. They may be shorter, or of the same length or even slightly longer than the longest P-R intervals of the preceding phase. They are usually long as in Fig. 1. The duration of the 2 : 1 block is variable, but generally continues for a minute or two. It is succeeded by a period of complete heart-block, in which the auricular rate is approximately twice that of the ventricle, but in which there is no simple arithmetical ratio between the rhythms of the two chambers. There is complete dissociation, and the auricular variations (P) fall at varying times in relationship to the ventricular

* This reappearance of 2 : 1 heart-block does not necessarily indicate a decrease of impairment of conductivity. It may be explained as a result of the slowing of an ideoventricular rhythm.

representatives (R and T). Frequently the representatives of auricle and ventricle coincide, a phenomenon well shown in Fig. 1 IV. The first P of this figure falls in the centre of the ventricular systole, the second in the middle of diastole, while the third coincides with and raises the apex of the variation T of the second ventricular systole. An auricular variation is known to have occurred at this instant, for the superimposition (comparing the T variations of the two ventricular cycles) is exact, and a P variation is expected at this point. We have a number of curves of complete heart-block produced in this way, but not so many examples as we have of the preliminary stages, for the condition of the animal becomes critical, and often re-establishment of respiration and recovery is desired. Nevertheless, recovery and absolute recovery of the conductive functions may occur subsequent to the period of complete dissociation, an event which we have thrice witnessed, and which is exemplified in Fig. 4 c.

The recovery from complete heart-block is relatively slow, and is pursued through similar stages to those of its production, though the order is reversed. Recovery from 2 : 1 heart-block is faster. There is a short latent interval of about 10 to 20 sec., and then within a few heart cycles the condition 2 : 1 heart-block passes to one of complete restoration; that is to say, the P-R interval returns to its original length at the commencement of the observation (Fig. 4 a and b). The change is the more remarkable for its suddenness, in view of the acceleration of auricular rate which accompanies it (Fig. 4 a and b). Recovery is permanent when it is complete.

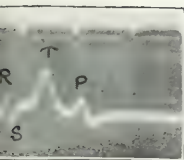
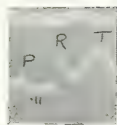
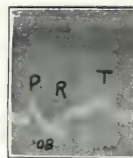
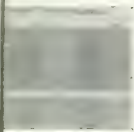
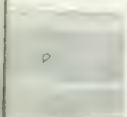
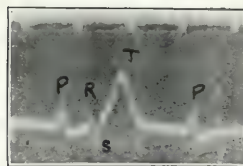
During the course of the experiments we have noted many other phenomena of interest, but these, being still obscure, we reserve—two further observations alone require description at the present time.

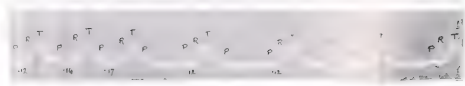
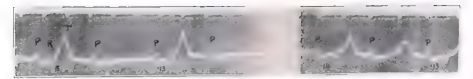
1). At or about the time when the heart appears to waver between a condition of 2 : 1 heart-block and regular sequential contraction accompanied by prolongation of the P-R interval, it not infrequently happens that passing into the latter state it exhibits a regular alternation of the P-R intervals. This in turn gives rise to a slight grade of ventricular bigeminy, for the long pause delays the onset of the ventricular systole for which it provides an impulse. We have no explanation to offer for the phenomenon; it is illustrated in Fig. 5.

2). The ventricular rate may increase at the onset of complete heart-block. This acceleration demonstrates the relative or absolute inactivity of impulse formation in the ventricle during the preceding stage of 2 : 1 heart-block. The auricular rate meanwhile may remain constant or diminish; it does not accelerate as does that of the ventricle.

CONCLUSIONS.

1. In the experimental animal, as a result of asphyxia, heart-block in the grades in which it is encountered in clinical cases, is of almost





regular occurrence. It commences within a few minutes of the cessation of ventilation, and is first manifested by a change of conductivity, a lengthening of the auriculo-ventricular systolic interval. It is observed in the intact curarised animal, with or without vagal section, in the decerebrate and the spinal animal, and after atropinisation.

2. All grades of heart-block, even complete, may be succeeded by speedy and complete recovery of conduction.

3. The heart-block is accompanied by a marked retardation of the auricular rate, and this likewise is independent of inhibitory influences.

4. Alternation of the P-R intervals, in the absence of dropped beats, is described.

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- ² SHERRINGTON. *Journ. of Physiol.*, 1909, XXXVIII, 381.

THE CAUSE OF THE HEART-BLOCK OCCURRING DURING ASPHYXIA.

BY G. C. MATHISON.*

(From the Institute of Physiology, University College, London.)

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INTRODUCTION AND DESCRIPTION OF METHOD.

THE present paper records the results of an investigation into the factors concerned in the production of the heart-block which is described in the preceding article. In asphyxia two main factors are at work, accumulation of carbon dioxide and deficiency of oxygen. To determine whether one or both of these factors is responsible for the heart-block appropriate experiments have been made. The chief observations were carried out on spinal, decerebrate and intact cats. Attention was directed towards the period at which heart-block comes on and its relation to changes in blood-pressure, auricular rate, and heart volume. The investigation was concerned only with heart-block from which recovery took place, so that the dissociation of auricle and ventricle in the last stages of the dying heart was not considered.

In all experiments the blood-pressure and pulse rate were recorded by means of the ordinary mercurial manometer; in some cases the ventricle volume was taken by means of the cardiometer referred to later. Except in a few cases, where continuous tracheal insufflation was employed, the animals were under ordinary artificial respiration; the double action pump devised by Hans Meyer was used, and by this means mixtures of gases were conveniently administered. In every experiment the temperature of the animals was kept at about 37 degrees centigrade by means of an electrically warmed operating table.

THE SPINAL CAT.*

The decapitated cat, first employed for experimental work by Professor Sherrington, presents many advantages in the investigation of portions of the circulatory mechanism. The withdrawal of anæsthetics after the initial operation of decapitation removes an interfering factor, and the absence of the medullary centres also simplifies matters.

To produce asphyxia all that is necessary is to discontinue artificial respiration, while if abolition of skeletal muscle movements is desired a smaller dose of curare suffices than in the intact animal. Young cats are most suitable, decapitation is more easily performed, and the lungs are healthier and less subject to the acute œdema which is apt to follow dilatation of the heart.

The preparations were made, with the exception of a few minor details, in the manner described by Sherrington¹. Before performing decapitation the vagi and depressors were severed and for convenience sake the carotid arteries and external jugular veins were double-ligatured and cut. The moment decapitation was performed anæsthetics were discontinued. Usually the actual experiments were not started till half an hour later, by

* The general behaviour of the spinal cat during asphyxia will be discussed elsewhere.

which time much of the chloroform had been eliminated and the preparation was in a more active condition.

The non-curarised spinal cat.—In such spinal animals the carotid pressure usually stands at about 60 mm. of mercury. The typical course of events during asphyxia is as follows :—

When artificial respiration is stopped the pressure at once rises a few millimetres and then gradually falls in about one and a half minutes to the neighbourhood of 30 or 40 mm. During the next half minute movements of the limbs and extensor spasms of the muscles occur, and there is a general rise of blood-pressure (usually to about 80 mm., but occasionally to more than double this pressure), and the heart rate is accelerated.

After reaching its maximum the blood-pressure quickly falls and the pulse slows to its former rate. Between three and four minutes after the start of asphyxia the amplitude of the oscillations of the mercury increases abruptly and the pulse rate is suddenly halved. Direct and electro-cardiographic observations of the heart at this period show that auricle and ventricle are beating at different rates, the ventricle ordinarily responding to every second ventricular beat. Heart-block may continue for two minutes or more without any further fall or blood-pressure; often, indeed, the ventricle works more efficiently and the blood-pressure rises a little. When artificial respiration is re-started the heart is rapidly restored to a normal condition; in 10 to 15 secs. the heart-block disappears, the pulse is greatly accelerated, rising to a considerably higher rate than at the beginning of the experiment; the blood-pressure rapidly increases generally to well over 100 mm., and is maintained at a high level for several minutes*. Fig. 1 illustrates some of the events related.

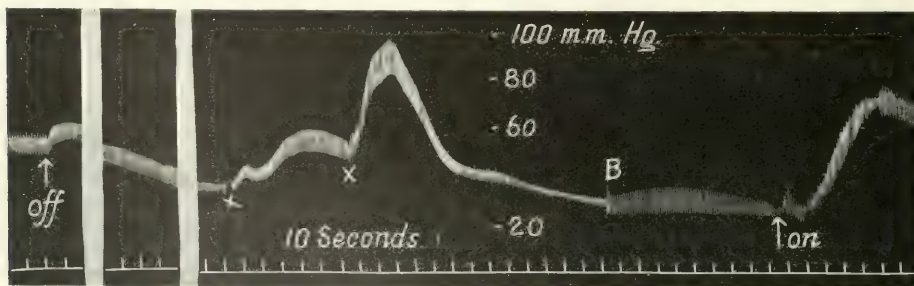


Fig. 1. $\times \frac{2}{3}$ linear. Heart-block during asphyxia in spinal animal. Cat, decapitated, non-curarised. Carotid blood-pressure record. Base line = zero pressure. Time intervals = 10 sec.. Artificial respiration stopped at off, resumed at on. The gaps indicate intervals of 30 sec.. At X spasms occurred. B indicates onset of 2 : 1 heart-block.

* The varying relations of auricle and ventricle before, during, and after the heart-block are described in the preceding article.

TABLE I.

CAT. SPINAL. NON-CURARISED.

Analysis of curve shown in Fig. 1.

Time in min. sec..	Carotid pressure in mm. Hg..	Rate of ventricle per min..	REMARKS.
0,0	55	138	Artificial respiration stopped.
0,7	60		
1,35	37		
2,5	36		Movements and muscular spasm.
3,0	55		
3,15	52		Extensor spasm.
3,25	89	138	
4,10	42	114	
5,10	32	54	Heart-block commences.
5,50			Respiration re-started.
6,55	28	54	Heart-block ends.
6,56		114	
8,0	72		
9,0	57	144	

The events during asphyxia in the spinal animal depend largely upon the condition of the heart and the excitability of the spinal vaso-motor centres. If the heart has been weakened or the spinal centre dulled by the chloroform or other agents employed, the rise of pressure at the time of the spasm is absent or of small dimensions. Heart-block nevertheless ensues, though its onset is usually delayed. If artificial respiration is not resumed soon after the onset of block, a heart so enfeebled rapidly fails beyond power of recovery. Direct observation of the heart shows that the auricular beats weaken progressively,* the ventricular beats are for a while relatively vigorous, but soon become feeble and ineffective. Then the auricular contractions cease, and all that is seen is a slight flutter at the mouths of the great veins; the ventricle contracts infrequently and in a short time stops permanently.

The curarised spinal cat.—For the purposes of some of the experiments it was essential to abolish muscular movements, and for this purpose curare, about 0.5 c.c. of a 2 per cent. solution, was injected into an external jugular vein. In the curarised spinal cat the arterial blood-pressure is, as a rule, slightly lower than in the non-curarised animal, but the general form of the blood-pressure curve during asphyxia is similar. Though the skeletal muscle spasms are absent, the vaso-motor discharges still take place, the rise of pressure being less abrupt. Heart-block appears during the period of low pressure which succeeds the rise and presents the same features as in the non-curarised cat.

The curare employed had sometimes a deleterious effect upon the heart, so that no rise of pressure took place; in such cases the blood-pressure fell

*It has been found to be difficult or impossible to record the movements with a myocardiograph.

steadily until artificial respiration was resumed ; then the pressure suddenly rose to a considerable height. The vaso-constriction had been present for some time, but the enfeebled heart had failed to respond. In these cases the appearance of heart-block was delayed, often till more than six minutes after the cessation of respiration ; recovery from block took place as usual shortly after the resumption of artificial respiration.

The changes in heart volume, which could not be studied in non-curarised animals, since the muscular movements would have displaced the apparatus employed, were investigated in curarised preparations by means of the cardiometer. Information was obtained as to the amount of dilatation and the output of the ventricles per beat. The cardiometer and volume recorder used were similar to those described by Jerusalem and Starling. In all cases the cardiometer was placed so that only the ventricles were enclosed. The changes during asphyxia are as follows : Soon after cessation of respiration the heart commences to dilate ; at first the output per beat is undiminished, but with more marked dilatation it decreases considerably. Suddenly the frequency of the heart beat drops to one-half, a sudden increase in diastolic volume occurs, and the output per beat increases. Gradual dilatation of the ventricles continues during block, and if artificial respiration is not resumed the heart beats more and more feebly and asystole ensues. If, however, respiration is re-started the ventricular rate increases to more than double that prevailing during the period of heart-block and the blood-pressure suddenly rises. The diastolic volume of the ventricles sometimes decreases at once, at other times increases, owing to increased filling, so that the highest blood-pressure and the maximum dilatation of the ventricles may be contemporary. In the majority of cases the ventricle remains for at least half a minute more dilated than it was at the onset of block. The systolic output equals or exceeds that which obtains during block and is usually greater than at the start of the experiment. In the course of a minute the dilatation of the ventricle disappears, the volume usually becomes less than the original volume, and the output per beat returns to the normal.

Fig. 2 illustrates an experiment in a large cat in which systolic output and dilatation of the ventricles during asphyxia were greater than usual. The onset of heart-block and the recovery from dilatation were both extraordinarily rapid. The general form of the blood-pressure curve is fairly typical for the curarised cat. In curves of ventricular volume, descent of the curve below the original level indicates dilatation, and if the volume recorder is calibrated, the actual amount of dilatation can be determined subsequently from the tracing. Similarly the size of the individual heart beats in the curve indicates the difference between the systolic and diastolic volume of each ventricular cycle ; that is to say, the volume of blood expelled from the ventricles at each contraction. According to calibration, in these experiments 5 mm. in the ordinate line represents a volume change of 1 c.c.*

* In the figures, the reductions must be allowed.

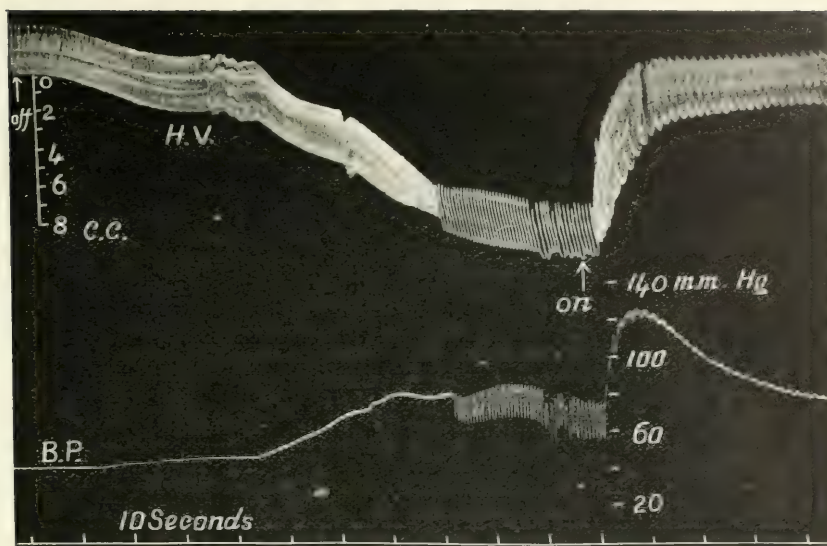


Fig. 2. $\times \frac{1}{2}$ linear. Heart-block and changes in heart volume during asphyxia in spinal animal. Cat, decapitated, curarised. B.P. = carotid blood-pressure. H.V. = volume of ventricle, the downstroke representing systole. In volume curve 5 mm. = 1 c.c. vol. Time intervals = 10 sec.. Artificial respiration stopped between the arrows. Onset of heart-block and dilatation of the ventricle, recovery.

TABLE II.

CAT. SPINAL. CURARISED.

Analysis of the curve shown in Fig. 2.

Time in min. sec..	Carotid blood-pressure in mm. Hg..	Ventricular rate per min..	Increase in diastolic volume in c.c.	Output of heart per beat in c.c.	REMARKS.
0,0	40	168	0	2.7	Artificial respiration stopped.
0,45	44		2.6		
1,10	81				
1,20	79	168	7.5	1.8	Heart-block starts. Respiration resumed. Heart-block ends.
1,23	74	84	8.5	3.0	
1,46					
1,52	66	60	10.5	2.8	
1,59	124	168	3.5	4.2	
2,25	80	168	1.2	2.6	

Want of oxygen.—In the production of asphyxia two main factors are at work, lack of oxygen and excess of carbon dioxide. The dissociation of the parts played by these factors in the production of heart-block is essential. Pure oxygen lack is obtained under artificial respiration, by substituting nitrogen for atmospheric air, and under these conditions carbon dioxide does

not accumulate, for it is washed out from the lungs as usual, and there is no increase in the CO_2 tension in the blood or the tissues. The oxygen in the lungs is soon replaced by nitrogen, so that the oxygen tension in the arterial blood may fall practically to zero.

In practice it is found advisable to employ nitrogen with an admixture of 1 to 2 per cent. oxygen, for the heart is apt to fail very rapidly when pure nitrogen is used. In both curarised and non-curarised spinal cats the course of events when nitrogen and 2 per cent. oxygen are administered is similar in its essential features to that produced by asphyxia in the same animals (see Fig. 6). The rise of blood-pressure is, as a rule, less than in ordinary asphyxia, for the heart is affected by the rapid withdrawal of oxygen. It must also be remembered that Jerusalem and Starling⁵ have shown that the presence of moderate percentages of carbon dioxide increases the work done by the heart under ordinary asphyxial conditions, and these moderate percentages are absent. The close resemblance between the effects of oxygen lack and asphyxia are shown in the third table.

TABLE III.

Asphyxia and want of oxygen in the spinal animal.

CAT. SPINAL. NON-CURARISED. HEART IN GOOD CONDITION.

	Time in min. sec..	Arterial pressure in mm. Hg..	Rate per min..	REMARKS.
Asphyxia	0,0	65	138	Respiration off.
	1,10	46		
	1,45	50		Movements and spasm.
	2,10	80	156	Convulsions.
	3,20	42	72	Heart-block starts.
	3,40			Respiration on.
	3,57	42	72	Heart-block ends.
	4,5	135		
	7,5	65	144	
Nitrogen + 2% oxygen 4 minutes later.	0,0	58	144	Nitrogen on.
	1,20	46		
	2,0	52		Spasm.
	2,15	72	162	Convulsions.
	2,40	50	78	Heart-block starts.
	3,5			Nitrogen off.
	3,40	51	78	Heart-block ends.
	3,55	150		
	8,0	60	144	

The changes in heart volume when nitrogen is employed are similar to those in ordinary asphyxia. Fig. 6, which will be discussed at a later stage, demonstrates the main features. When the blood-pressure curves are alike in the two conditions the curves of ventricular volume also manifest close resemblance. In the majority of cases the systolic output and the dilatation

of the ventricle, at the moment when heart-block occurs, are less with nitrogen, but in other respects the curves are almost identical.

The effect of excess of carbon dioxide.—Attempts were made to produce heart-block by administering large concentrations of carbon dioxide to spinal cats, curarised and non-curarised. According to Kaya and Starling² the administration of carbon dioxide in the presence of adequate amounts of oxygen causes no rise in blood-pressure in the spinal animal. By employing mixtures containing 25 per cent. and upwards of carbon dioxide with adequate amounts of oxygen, I have produced large rises of pressure. For example, a mixture of 36 per cent. carbon dioxide and over 50 per cent. oxygen caused a fall of pressure from 74 mm. Hg. to 34 mm. in one minute; three minutes later the blood-pressure had risen to 194 mm., and it remained at a high level for over two minutes, only falling after the administration of the mixture ceased. During many experiments, in which mixtures containing carbon dioxide in proportions ranging from 5 per cent. up to 67 per cent. (in the latter case the oxygenation of the blood was probably less than the normal) have been given, I have never succeeded in producing heart-block, though in some cases the administration has been continued as long as 10 minutes. Further evidence that carbon dioxide plays no part in the production of heart-block is afforded by experiments in which this gas was administered during a period of heart-block. The results show that carbon dioxide is not only incapable of producing heart-block, but also of maintaining a pre-existing block. For example, in one experiment in which the heart-block had been present for over a minute, a mixture containing 67 per cent. carbon dioxide and 25 per cent. oxygen was given. The heart-block terminated within 15 secs..

The effect of paralysing the vagus endings.—The fact that it is possible to produce heart-block by vagus stimulation necessitated an enquiry as to its participation in the production of heart-block during asphyxia. In the spinal animal the cardio-inhibitory centres are absent, but current conceptions of the nature of nerve endings admit the possibility of the direct stimulation of the peripheral vagus endings by chemical substances. To exclude any effect of oxygen lack or carbon dioxide excess upon the vagus endings, atropine was injected in doses which rendered strong faradic stimulation of the vagus trunk in the neck ineffective. This paralysis of the vagus endings was without effect on the onset or character of the block (cf. Sherrington¹).

THE DECEREBRATE CAT.

In common with the spinal animal, the decerebrate animal possesses the advantage that after the initial operation anaesthetics are unnecessary. On the other hand, the use of curare is necessary to abolish respiratory movements.

Method.—Under full anaesthesia the trachea was opened and artificial respiration instituted. The carotids were both ligated and the vagi and depressors divided. The skull was trephined over the most prominent part

of the parietal bone and decerebration performed by means of a blunt instrument at the level of the anterior border of the bony tentorium. The brain stem was thus transected at the level of the upper part of the posterior corpora quadrigemina. Decerebration completed, anæsthetics were discontinued and 1 c.c. of a 2 per cent. solution of curare was mixed with 10 c.c. of saline and injected into an external jugular vein.

Since the medullary vaso-motor mechanism is active the blood-pressure is high, usually 150 mm. or more. The cessation of artificial respiration is rapidly followed by a rise of pressure. The pressure remains high for a minute or less, then suddenly falls, the descent being so rapid that individual heart beats are indistinguishable in the tracing. The steep descent (often of 100 mm. Hg.) is just as abruptly retarded, and at this point the amplitude of the oscillations of the mercury is found to be greatly increased and the heart is seen to be beating at half its previous rate. The blood-pressure continues to fall, but less rapidly, until artificial respiration is resumed. Then in a few seconds the heart rate increases and the blood-pressure rapidly rises, though for some time it fails to attain its original level. These changes are illustrated in Fig. 3. In this experiment the blood-pressure is extremely high even for the decerebrate cat, but the sequence of events is sufficiently typical.

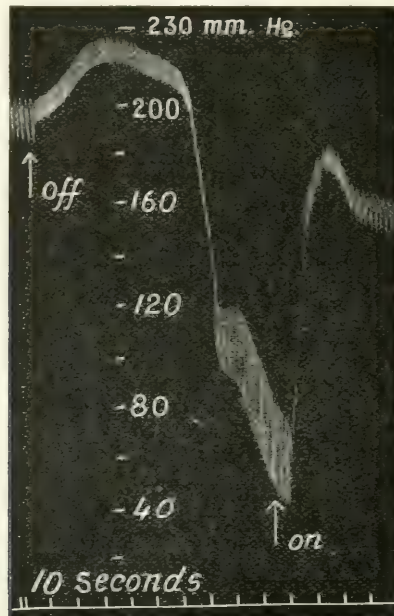


Fig. 3. $\times 3$ linear. Heart-block during asphyxia in decerebrate animal. Cat, decerebrate, curare. Both vagi cut. Carotid blood-pressure record. Respiration off between the arrows. Onset of block after sudden fall of pressure. Note abrupt fall of blood-pressure and onset of heart-block.

TABLE IV.

CAT. LARGE MALE. $4\frac{1}{2}$ KILOS. DECEREBRATE. VAGI CUT. 2 c.c. 2% CURARE.

	Time in min. sec..	Carotid pressure in mm. Hg..	Rate per min..	REMARKS.
Asphyxia I.	0,0	146		Respiration off.
	0,30	162		
	1,15	186	180	
	1,25	85	90	Heart-block.
	1,45			Respiration on.
	1,50	56	90	End of heart-block.
	2,0	158	180	
	2,35	172		
Asphyxia II. 3 minutes later. (Fig. 3.)	0,0	194		
	0,27	219	180	
	0,55	200		
	1,5	108	90	Heart-block.
	1,17			Respiration on.
	1,24	58	90	End of heart-block.
	1,33	176	180	
Nitrogen* 3 minutes later.	0,0	121	180	Nitrogen on.
	0,20	117	180	
	0,30	124		
	1,0	186		
	1,10	180	180	
	1,15	101	90	Heart-block.
	1,20		90	
	1,21	124	180	Escape from heart-block.
	1,26		180	
	1,27	88	90	Heart-block.
	1,36		90	
	1,37	100	180	Escape from heart-block.
	1,43		180	
	1,44	70	90	Heart-block.
	2,8		90	Respiration on.
	2,20	64	90	End of heart-block.
	2,30	174	180 +	
	2,40	186		
	3,20	150	180	

In the decerebrate cat the effect of oxygen want is practically the same as that of asphyxia except that the rise of pressure occurs a little later and may be preceded by a slight preliminary fall. The table gives the analyses of Fig. 3 and of two other curves from the same cat, illustrating the changes under asphyxia and under oxygen lack produced by administering nitrogen.

* The temporary escapes from ventricular slowing which occurred during this experiment were possibly due to the leaking in of small quantities of air at some point in the artificial respiration apparatus.

In all decerebrate cats heart-block* has been readily produced by asphyxia or nitrogen; in all cases the onset was rapid and never later than 2 mins. after the start. The explanation of this rapid onset will be discussed later.

The effect of carbon dioxide.—As in the spinal cat so also in the decerebrate, excess of carbon dioxide failed to produce heart-block. For example, in the cat upon which the experiments detailed in Table IV were performed 42 per cent. carbon dioxide and 40 per cent. oxygen were administered for 9 mins. The blood-pressure rose in 2 mins. from 150 to 210 mm., and remained at a high level during the whole period, but no heart-block ensued.

THE INTACT CAT.

The present experiments were carried out upon cats with and without the vagi intact. Urethane was employed as the permanent anæsthetic, in order to avoid the depressant action of chloroform on the circulation in general and the heart muscle in particular. The cat was first anæsthetised with chloroform. The trachea was opened and artificial respiration instituted. Urethane, 4 c.c. of a 25 per cent. solution per kilo body weight, together with 1 c.c. of a 2 per cent. solution of curare, was injected into an external jugular vein and the chloroform was discontinued. If owing to the outbreak of spontaneous respiratory movements during the course of the experiments more curare was found necessary it was injected with an equivalent of urethane into the vein.

The effects of asphyxia, of nitrogen and of carbon dioxide were investigated.

For some of these experiments a special method of artificial respiration was employed. The results obtained when nitrogen was given by the ordinary respiration apparatus were not always perfectly satisfactory, firstly, because there was considerable dead space, and secondly, because there were one or two points at which communication with the outer air, and consequent leakage, were possible. In several experiments a modification of Meltzer and Auer's³ method of continuous intra-tracheal insufflation was employed. The principle of their method is the passage of a continuous stream of air into the lungs under pressure. Currents of air enter and leave the lungs without altering their size, and they remain appropriately distended. Efficient pulmonary ventilation is easily secured, the lungs are in a continuous condition of moderate distension, and, since no movements take place, the ordinary respiratory undulations of blood-pressure are absent.

* In one decerebrate cat, when heart-block appeared, the ventricle contracted at one-fourth its former rate. By direct inspection it could not be ascertained whether this was a true 4:1 rhythm or an independent ventricular rhythm, but it is remarkable that heart-block was produced five times in this cat, and in every case the rate fell suddenly from 40 beats per 10 secs. to 10 per 10 secs.

The method is particularly valuable in experiments where the cardiometer is employed, as the heart volume curve is considerably affected by the ordinary method of artificial respiration. The following modification of the original method has been adopted. The trachea is opened in the neck a little below the cricoid cartilage, and a glass tube about 6 cm. long and of 7 mm. internal diameter is inserted and tied in so that about 2 cm. projects outside the trachea. A glass tube of 3 mm. internal diameter is passed down inside this as far as the bifurcation of the trachea and then withdrawn a little so that its termination lies about 1 cm. above the bifurcation. The outer end of the small tube is connected with a cylinder of oxygen in such a manner that when the oxygen is turned on it passes first through a Woulff's bottle containing hot water and then through coils of lead tubing immersed in hot water. The oxygen, which becomes very cold when it escapes from the cylinder, is thus raised to a proper temperature. The rate at which the gas passes can be gauged from the amount of bubbling in the Woulff's bottle. After a few trials the rate can be nicely adjusted, so that the lungs are sufficiently ventilated without being unduly distended. When the correct amount of ventilation is attained the blood-pressure and pulse rate remain steady. Immoderate distension brings about an immediate fall of pressure. With insufficient ventilation the blood-pressure gradually rises owing to accumulation of carbon dioxide. On the other hand, if the ventilation is too great the blood-pressure falls and the pulse rate increases, a condition of acapnia being produced. By means of a Y junction in the connections just above the glass tracheal tube nitrogen or any other gas can be instantly substituted for oxygen. This gas passes through a similar heating system, and before it is turned on its rate can be approximated to that of the oxygen. When this second gas is substituted for the oxygen any difference in ventilation is at once manifested by a change in blood-pressure, and, if necessary, an adjustment can be made. The dead space is extremely small when this method is employed; the substituted gas has to displace the original gas from only a few centimetres of narrow tubing before reaching the lungs. Ordinary artificial respiration can be substituted at any moment by connecting the supply tube, in the course of which there is a side vent to allow the expired air to escape, with the outer tracheal tube.

The cat with vagi intact.—The blood-pressure curves during asphyxia and during the administration of nitrogen show a general resemblance. In asphyxia the rise of pressure is smaller and more gradual; with nitrogen it is rapid and of considerable magnitude. During asphyxia, marked slowing of the heart appears at an early stage, and persists up to the onset of block, and irregularity of the pulse rate is frequently present; with nitrogen less slowing is seen and the heart as a rule beats regularly. In asphyxia inhibition of the heart (from which it only escapes when the vagi are cut) may take place before heart-block appears.

Heart-block comes earlier with nitrogen. If respiration is resumed 20 or 30 secs. after the onset of block, recovery rapidly takes place

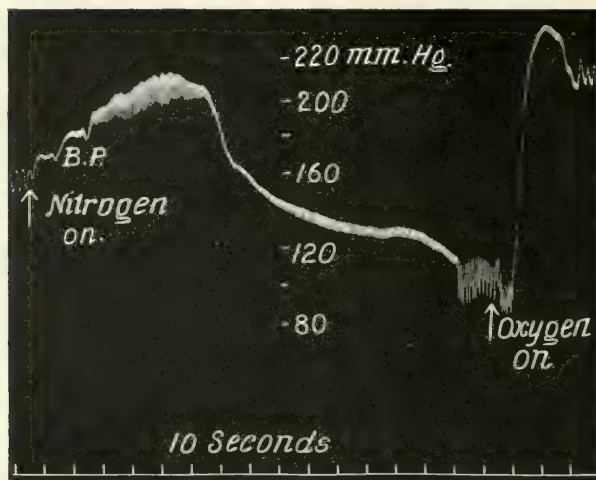


Fig. 4. $\times \frac{1}{2}$ linear. Heart-block during administration of nitrogen in animal with vagi intact. Cat, urethane, curare. Nitrogen + 1% oxygen administered by continuous tracheal insufflation at first arrow; oxygen substituted at second arrow. Carotid pressure record. Base line = zero pressure. Time intervals = 10 sec.. Note slowing of heart by vagus action in early stages.

TABLE V.

CAT. SMALL. URETHANE. CURARE 1.1 c.c. OF 2% SOLUTION. VAGI INTACT.

Analysis of the curve shown in Fig. 4.

Nitrogen by con- tinuous tracheal insufflation (Fig. 4).	Time in min. sec.,	Carotid pressure in mm. Hg.,	Rate per min.,	REMARKS.
	0,0	154	180	Nitrogen.
	0,2	165		
	0,42	204	132	
	0,55	200		
	1,0	164	144	
	2,26	112	144	
	2,27	103	78	Heart-block.
	2,42	104		Nitrogen off and oxygen on.
	2,52	95	78	End of heart-block.
	3,0	235	192	
	3,15	206	180	
Asphyxia 5 minutes later.	0,0	156	228	Respiration off.
	0,2	166	228	
	0,25	180	204	
	0,50	190	148	
	1,10		138	
	1,40	172	132	
	3,10	67	60	Heart-block.
	3,28			Respiration on.
	3,40	76	72	End of heart-block.
	3,55	234	228	
	4,10	200	228	

and the blood-pressure rises to a considerable height. If the resumption of respiration is deferred the heart may be suddenly inhibited and though it may escape for a moment, complete inhibition soon follows and recovery only ensues when the vagi are cut.

The events under nitrogen are illustrated in Fig. 4. An analysis of this experiment, and of a companion experiment in asphyxia, are given in Table V.

The cat with vagal connections destroyed.—When the vagi are cut heart-block comes on more rapidly than when they are intact. With the onset of asphyxia the blood-pressure rises more rapidly and falls much more rapidly; the sudden fall is arrested by the onset of block, the curve at this point resembling that of the decerebrate animal. The pulse is not slowed during the early stages, no noticeable alteration in rate taking place until the heart-block stage is reached. The ventricular rhythm during heart-block is perfectly regular in the animal with intact vagi. A comparison of the pulse rates in Tables V and VI will demonstrate the difference in the behaviour of the heart in the cat during asphyxia before and after section of the vagi. In experiments on animals under chloroform anæsthesia, particularly on dogs, the differences are much more striking. When the vagi are intact not only is the heart rate retarded but temporary stoppages are frequent; when the vagi are cut the early slowing and long pauses are never present.

The production of heart-block by want of oxygen is illustrated by Fig. 5, which is taken from an experiment on the same cat as Fig. 4. Both vagi were cut and 1·700 gramme atropine sulphate was given. The smallness of the rise in pressure was probably due to two factors: the heart was enfeebled as a result of the repeated asphyxia and of an additional dose of curare which had been found necessary, and the excitability of the vasomotor centre was depressed from the same causes. The figure was chosen on account of the long duration of heart-block which it shows.

Table VI gives the analysis of the curves of this and a companion experiment.

The effect of carbon dioxide on the cardio-inhibitory centre.—In the intact animal, as in the spinal and decerebrate, carbon dioxide fails to produce block, but some of the results are of interest as they show that carbon dioxide stimulates the cardio-inhibitory mechanism. In an experiment on a cat under chloroform anæsthesia a mixture containing 21 per cent. carbon dioxide and 30 per cent. oxygen produced great slowing of the heart. In less than a minute the pulse rate fell from 32 per 10 secs. to 7 per 10 secs., and great dilatation of the heart occurred. At this point air was substituted. The heart stopped for 5 secs., and in the succeeding 10 secs. it contracted five times. A minute later the rate was 12 per 10 secs., and in the next 2 mins. it returned to the normal. The vagi were then cut and the same mixture of carbon dioxide was given for over 4 mins. Considerable dilatation again occurred, though not so great as when the vagi were intact, but the heart rate remained unchanged. The increased

tension of carbon dioxide in the blood is thus a powerful stimulant to the cardio-inhibitory centre and plays a part in the vagus slowing seen during asphyxia in the intact animal.

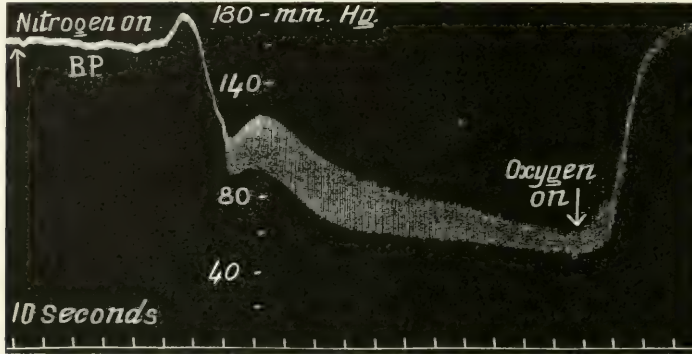


Fig. 5. $\times \frac{1}{2}$ linear. Heart-block during administration of nitrogen in animal with vagi cut. Same cat as in Fig. 4, but after additional doses of curare and urethane, and 1/700 gramme atropine sulphate. Nitrogen + 1% oxygen administered by continuous tracheal insufflation between the arrows, then oxygen substituted. Carotid pressure record. Long duration of 2 : 1 heart-block.

TABLE VI.

CAT.	SMALL.	URETHANE.	CURARE.	VAGI CUT.	ATROPINE SULPHATE $\frac{1}{700}$ GRAMME	
	Time in min. sec.,	Carotid blood-pressure in mm. Hg.,	Rate of ventricle per min.,	REMARKS.		
Asphyxia.	0,0	148	192	Respiration off.		
	0,2	158				
	0,50	152				
	1,5	157	198			
	1,18	86		Heart-block. Respiration on. End of block.		
	1,20	80	96			
	1,30					
	1,38	67	96			
	1,45	122	198			
	1,55	146				
Nitrogen (5 minutes later), with 1% oxygen by continuous tracheal insufflation (Fig. 5).	2,53	172	192			
	0,0	162	204	Nitrogen on.		
	0,45	162				
	0,55	176	192	Heart-block.		
	1,5	104	96			
	1,20	112				
	3,8			Oxygen on. End of block.		
	3,22	62	78			
	3,35	101	174			
	3,43	157	180			
	3,55	170	186			

HEART-BLOCK IN THE DOG.

The blood-pressure curve during asphyxia in the dog with intact vagi shows great slowing of the heart, as a result of inhibitory influences, and the curve presents an irregularity which is considerable and is particularly prominent when chloroform is the anæsthetic employed. In a number of curves examined heart-block is not apparent.

When the vagi are cut heart-block during asphyxia appears to be a regular event. In three out of four curves the blood-pressure reached its maximum in less than a minute; in less than 2 mins. from the start heart-block commenced, the blood-pressure being at this time at about its original level. In the fourth case block did not ensue till 4 mins. had elapsed. All these dogs were anæsthetised with large doses of morphia.*

THE RELATIONSHIP OF HEART-BLOCK TO BLOOD-PRESSURE, AURICULAR RATE AND VENTRICULAR VOLUME DISCUSSED.

Blood-pressure.—The time of onset of heart-block and its relation to changes in blood-pressure during asphyxia are shown in Table VII in which averages from a number of experiments are given.

TABLE VII.
BLOOD-PRESSURE AND HEART-BLOCK DURING ASPHYXIA.†

Animal.	No. of Observations.	Arterial pressure at start in mm. Hg..	Maximum arterial pressure before onset of H.B.		Heart-block.	
			Height in mm. Hg..	Time of occurrence after start in min. sec..	Arterial pressure at onset in mm. Hg..	Time of onset in min. sec..
Spinal Cat, non-curarised..	15	55	82	2,12	41	3,10
Spinal Cat, curarised ..	10	48	74	2,33	51	3,5
Decerebrate Cat ..	9	151	182	0,57	71	1,30
Intact Cat, with Vagi cut..	10	121	145	1,3	71	2,6
Dog, Vagi cut ..	4	92	160	1,12	99	2,8

The table shows that an originally high blood-pressure favours the early appearance of heart-block. The heart works more vigorously and the activities of the animal are at a high level; the oxygen available in the blood is exhausted with greater rapidity than in those animals in which the blood-pressure is originally low.

* I am indebted to Dr. C. J. Martin for the opportunity of examining many tracings of asphyxia in dogs.

† The observations on cats with intact vagi are not included, since, owing to the onset of cardiac inhibition, heart-block does not invariably appear. The results of experiments on certain spinal cats upon which asphyxia seemed to produce little effect are also excluded. These animals were from various causes in an inactive condition, their blood-pressure was very low, and their spinal reflexes inexcitable.

That the heart-block is not a direct result of changes of blood-pressure is clearly demonstrated by the employment of the several experimental preparations. Reference may be made to the preceding figures and tables. The onset of heart-block, with a simultaneous deep depression of blood-pressure, is shown to advantage by the decerebrate animal (Fig. 3, and Table IV). On the other hand, the blood-pressure in the spinal animal (Figs. 1 and 6) may show little alteration immediately at the onset or offset of the block; there may be a good deal of change during the actual period of block, and the pressure during the heart-block stage may actually exceed that which is present at earlier stages of the experiment (Figs. 2 and 6). In brief, the heart-block which occurs in asphyxia is not directly dependent upon blood-pressure changes, but heart-block and blood-pressure change are each and separately the outcome of asphyxia.

Auricular rate.—Until the onset of heart-block the pulse rate in animals with the vagi cut undergoes but little alteration. There is usually an increase of rate during the rise of pressure, but the heart slows to the original rate before block occurs. During the stage of heart-block the auricular rate is often retarded, so that the ventricle, responding to every second auricular contraction, beats at less than half its original rate.

Heart volume.—Both in the asphyxial experiments and in those in which mixtures of nitrogen and oxygen were administered dilatation of the heart ensues, and the question arises as to whether the mechanical stretching of the heart muscle may be directly responsible for the production of heart-block.

To settle this question attempts were made to produce an equal degree of dilatation by means of carbon dioxide and lactic acid. It was found impossible to do so except by employing these agents in such quantities that asystole occurred.

Indirect evidence is obtained from a study of ventricular volume curves. In all of these the diastolic volume of the ventricle is greater at the moment of recovery than it is at the onset of block (Fig. 6).

Frequently the ventricle continues to dilate after the resumption of the regular auriculo-ventricular sequence, the maximum dilatation being present at about the same time as the maximum arterial pressure succeeding heart-block. In some cases the ventricle does not contract to the volume which obtained at the onset of block until nearly a minute after block has ceased. These volume changes are illustrated in Fig. 6. Further, the degree of dilatation present when heart-block is produced by asphyxia is not necessarily the same as when it is produced by the administration of nitrogen in the same animal. In the majority of cases the dilatation produced by asphyxia is greater. In one and the same experiment the amount of dilatation may show variation amounting to as much as 2.5 c.c. in a total dilatation of 6 c.c.

Evidence has also been obtained by minimising the amount of dilatation. To do this the rubber tube which connects the cardiometer and the volume recorder is clamped. Direct observation of the ventricle under these con-

ditions shows that the amount of dilatation is very small compared with that ordinarily produced. A comparison of Figs. 6 and 7 shows that heart-block comes on as readily when the dilatation is minimised as when it is allowed to reach its full dimensions.

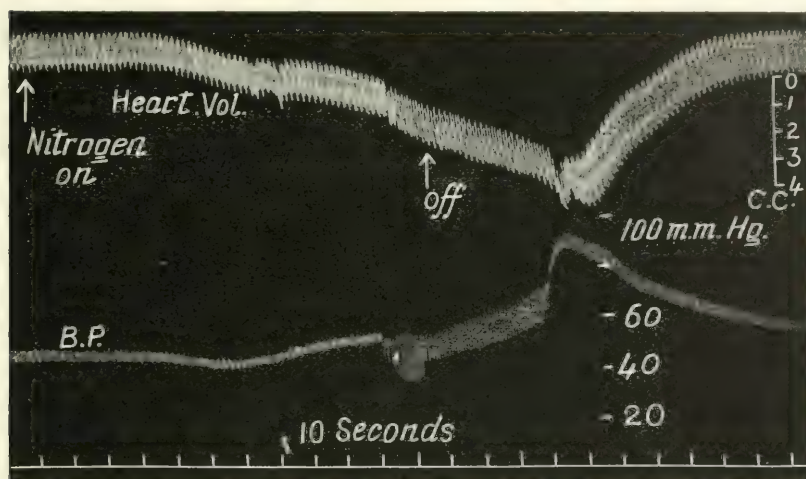


Fig. 6. $\times \frac{2}{3}$ linear. Heart-block and changes in heart volume during administration of nitrogen in spinal animal. Cat, decapitated, curarised. Nitrogen with 2 % oxygen given between the arrows. B.P. = Carotid pressure. In heart volume curve downstroke indicates systole; 5 mm. = 1 c.c. volume. The amount of dilatation is to be compared with that in Fig. 7.

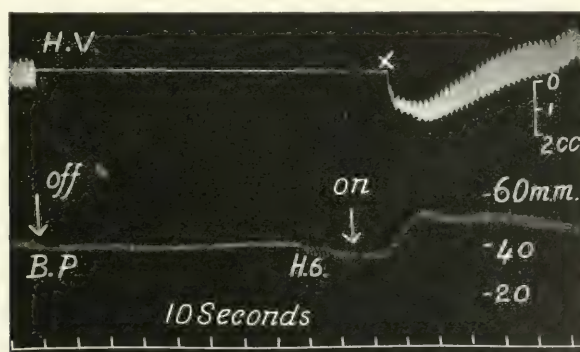


Fig. 7. $\times \frac{2}{3}$ linear. Heart-block during asphyxia without much dilatation of the heart. Same cat as in Fig. 6, but not in such good condition. Respiration stopped between the arrows. B.P. = Carotid pressure. H.V. = Ventricular volume. Outlet tube of cardiometer clamped so that dilatation was minimised. At X outlet tube released. H.b. indicates onset of block. Amount of dilatation to be compared with that in Fig. 6.

THE MODE OF CAUSATION OF THE HEART-BLOCK.

Earlier in this paper it was shown that of the two essential factors in asphyxia, lack of oxygen and accumulation of carbon dioxide, it is upon the former that heart-block depends.

Now the term "lack of oxygen" covers a number of changes in metabolism in relation to which deficiency of oxygen stands as the causative factor. For example, when the supply of oxygen is insufficient the katabolic processes in the cells are incomplete, and, as Fletcher and Hopkins¹ have shown, intermediate katabolites, such as lactic acid, accumulate in the tissues. It must be understood that the effect of "lack of oxygen" is due to a number of chemical agencies of the exact nature of many of which we are at present ignorant.

Among the results of the action of these various agencies are a rise in blood-pressure and dilatation of the heart. It is conceivable that these mechanical variations in the circulation might be directly responsible for the production of heart-block, but the experimental results have shown that they are not involved.

It is to some other effect of "lack of oxygen" that heart-block is due. It is probably attributable to a depression of the conductivity of the auriculo-ventricular connections by an accumulation of intermediate products of metabolism within the cells of the musculature.

CONCLUSIONS.

1. Heart-block, from which recovery is readily brought about, occurs during asphyxia in spinal cats, decerebrate cats, and intact cats when the vagi are cut. When the vagi are intact and great slowing of the heart occurs, this heart-block may fail to appear before permanent inhibition ensues.

2. The onset of heart-block is more rapid when the blood-pressure is high, but the occurrence of block is independent of the alterations in blood-pressure which occur during asphyxia.

3. Of the two factors present in asphyxia, want of oxygen and accumulation of carbon dioxide, the former alone is responsible for the production of block.

4. The heart-block is undoubtedly due to the effect of want of oxygen on the cardiac tissues. Marked dilatation of the heart occurs, but this is not the essential factor. The depressant action of want of oxygen, or of substances produced as the result of want of oxygen, upon the auriculo-ventricular connections, is the essential factor.

5. In animals in which the vagi are intact, especially where chloroform is the anæsthetic employed, irregular slowing which has no connection with

heart-block, frequently occurs during asphyxia. This slowing is due to stimulation of the cardio-inhibitory centre.

6. Heart-block appears to be a regular occurrence during asphyxia in dogs in which the vagi are cut. When the vagi are intact permanent cardiac inhibition frequently comes on before heart-block can appear.

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PAROXYSMAL TACHYCARDIA ARISING FROM TWO DISTINCT FOCI IN THE AURICULAR TISSUE IN A SINGLE PATIENT.

By H. F. MARRIS.

(*From the Mount Vernon Hospital.*)

IN a paper published in the last number of this *Journal* (Lewis, *Heart*, 1909-10, I, 361, Case 15) a case of paroxysmal tachycardia was reported, and facts were brought forward to show that the mechanism of the heart during the paroxysms was such that auricle and ventricle contracted simultaneously. This conclusion rested upon the nature of the venous curves, wherein, during the paroxysms, prominent waves having the general character of *a* waves occurred. These waves were of increased amplitude as compared to the *a* waves of the normal rhythm, and the *a-c* intervals were reduced from the normal 0.2 sec. to 0.06 sec. (Fig. 27 of that paper). Further, evidence in the nature of electrocardiograms was put forward, for in these curves the normal P-R interval of 0.14 sec. was decreased to 0.08 sec. during the paroxysms. It was considered probable that the paroxysms arose from a point lying between the pace-maker and the ventricle, both on account of the shortening of As-Vs* interval and on account of the conformation of the auricular representative (the complex P) in the electric curve, and it was suggested that the point of generation of impulses lay in the neighbourhood of Tawara's node.

Further observations upon the same case have proved of interest. Two paroxysms are shown in the accompanying figures; the curves were taken with a polygraph, and the patient was in the recumbent posture, as was also the case in the instance of the three original polygraph curves.

Fig. 1 presents an interruption of the normal rhythm by a brief paroxysm of four beats, and by a single premature beat of a similar nature. During the paroxysm, the rate of the ventricle rises abruptly from 72 to 125 per minute. Accompanying each of the rapid beats are distinct *a* and *c* waves, and the *a-c* intervals are from 0.15 to 0.18 sec. in duration. The paroxysm ends in a prolonged pause.

The commencement of a second and longer paroxysm is shown in Fig. 2. The rate of the ventricle rises immediately from 75 to 125 beats per minute, and, as in the case of Fig. 1, the paroxysm is accompanied by distinct *a* and *c* waves in the jugular pulse. The *a-c* intervals are from 0.15 to 0.19 sec. in duration.

* The auricular systolic to ventricular systolic interval; the shortening of which is evidenced by decrease in *a-c* and P-R intervals.

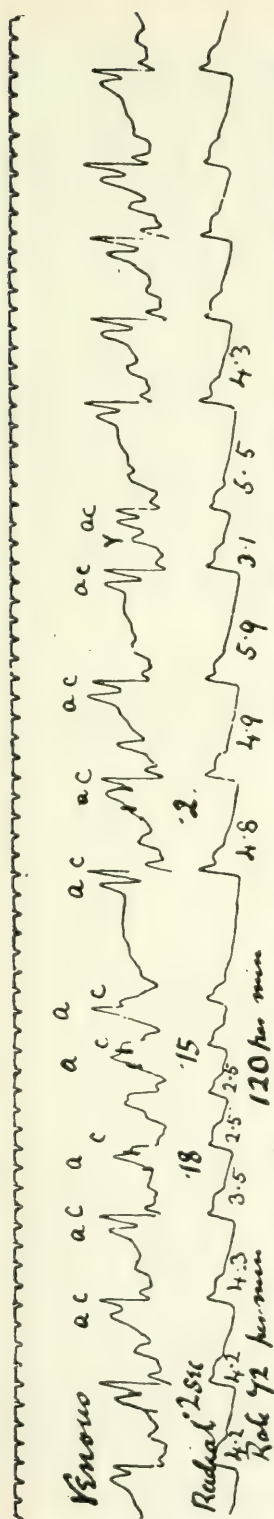


Fig. 1. A tracing taken from a case of paroxysmal tachycardia. A short paroxysm of four beats is shown, and it arises in the auricle. The succeeding rhythm of the heart is interrupted at one point by a single premature auricular contraction.

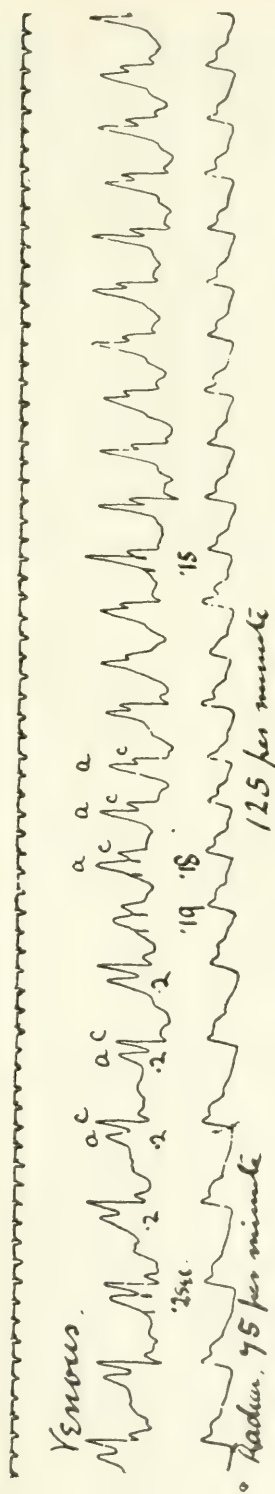


Fig. 2. The onset of a long paroxysm from the same case. The nature of the paroxysm is the same as that of Fig. 1, that is to say, it arises in the auricle.

The present instances, the two figured paroxysms, are paroxysms the nature of which cannot be doubted. They are due to pathological impulse formation, and are independent of inhibitory influences, for the onsets and offset are abrupt, and the paroxysm of the first figure terminates in a prolonged pause. Moreover, one is led to suggest, from the length of the pause in question, that the paroxysm has arisen ectopically, that is to say from a point other than the pace-maker, for the pause greatly exceeds the interval between two beats of the normal rhythm. But while this argument cannot be held as conclusive, it receives support from the slight reduction of the *a-c* intervals accompanying the paroxysms.

The paroxysms are of an obviously distinct type to those previously recorded for this case, and the *a-c* intervals and the difference between them in the original curves and in those now given are in themselves sufficient to demonstrate that, while the original paroxysms arose from the lowest levels of the auricular tissue, the present paroxysms are of higher origin.

The observations are of importance in that they exemplify what has not been reported hitherto, namely, the origin of paroxysms in one and the same subject from two distinct points in the auricular tissue.

CONCLUSION.

Paroxysms of rapid heart beats may be generated from at least two separate foci in the auricular tissue of one and the same clinical subject.

A CASE OF COMPLETE HEART-BLOCK IN DIPHTHERIA, WITH AN ACCOUNT OF POST-MORTEM FINDINGS.

By G. B. FLEMING AND ALEX MILLS KENNEDY.

(*Glasgow.*)

HEART-BLOCK is a condition which has been fairly fully investigated in chronic heart disease, but only a few cases have been reported in acute affections of the heart. Possibly this is not due to the great rarity of the condition, but to the fact that it has been recognised only occasionally. Cases have been described in influenza,⁵ rheumatic fever,^{1 & 2} ulcerative endocarditis,^{3 & 4} typhoid,⁶ pneumonia,⁶ and in one case of diphtheria,⁶ but in only four cases have post-mortem examinations been made. In one, a case of acute rheumatism reported by Gerhardt, the block lasted for at least two months; eventually the patient contracted enteric fever, and died 3½ months after the commencement of the attack of rheumatic fever. Inflammatory lesions were found in the auriculo-ventricular bundle. In the second case (James) ulcerative endocarditis was the cause of death, and an ulcer was found on the left surface of the intraventricular septum immediately beneath and posterior to the undefended space; no microscopical examination was made. In the third case (Jellinek and Cooper) death was due to acute gonorrheal endocarditis; there was an acute necrosis of the intraventricular septum with thrombosis of blood-vessels, and there can be no doubt that the A-V bundle was involved in the lesion. Lastly, Magnus-Alsleben⁶ describes a case of complete heart-block in diphtheria in a child aged 8 years. An examination of the heart including the A-V. bundle showed the presence of a very severe parenchymatous degeneration.

In the course of an investigation into the heart's action in acute fevers the following case came under observation.

The patient, a female, 10 years of age, was admitted to Ruchill Hospital, Glasgow, on the fifth day of illness, suffering from typical diphtheria of a severe type. She was a poorly nourished and neglected child. On admission the temperature was 99·2°, the pulse 96, and the respiration 24. The tonsils and pharynx were congested; the right tonsil was slightly ulcerated; there was a considerable quantity of loose dirty membrane on the back of the throat. The toxæmia was severe.

Nothing abnormal was found in either the heart, lungs, abdomen, or urine; 8000 units of antitoxic serum were given on the day of admission; the illness was of 10 days' duration. On the sixth day of illness, the day after admission, the patient's pulse rate fell to 62; it rose again on the seventh day as high as 88, but fell on the evening of that day to 40. On

the eighth day it varied between 80 and 52; on the ninth day its maximum speed was 72, its minimum 48; on the tenth day its lowest rate was 40, its highest 62. From the sixth day until death the temperature varied between 99° and 97·4°. Two days before death occurred the heart was considerably dilated, the left border of cardiac dullness was 3½ inches from the middle line, the right border in the middle line, the upper border in the third interspace; the apex beat was in the fifth interspace 3¼ inches from the middle line. Pulsation was visible in the third, fourth, and fifth left interspaces. There was very rapid and obvious pulsation in the neck, immediately above the clavicles, which tracings showed to be due to auricular contractions. The first sounds were somewhat soft and muffled, the second was occasionally duplicated. No sounds corresponding to the auricular contractions could be heard. On the day before death there were signs of palatal paralysis, the voice was nasal and fluids were regurgitated through the nose. The patient died on the tenth day of illness. Permission was obtained for a post-mortem examination of the heart alone. It was found to be distinctly dilated and rather pale in colour. Both the aortic and pulmonary valves were competent; the mitral valve admitted two fingers with ease, and the tricuspid three. A block of tissue was removed from the cardiac septum which contained the *pars membranacea septi*, the adjacent portions of the auricular and ventricular muscular septa, the central fibrous body and the attachments of the aortic cusp of the mitral valve, and the septal cusp of the tricuspid valve. The block extended sufficiently far back to include the mouth of the coronary sinus. It was cut out in such a manner that its long antero-posterior diameter was at right angles to the long axis of the heart.

This block was cut in serial sections from above downwards, in the horizontal plane. Nearly 400 sections were cut, and a series at intervals of five were mounted. The sections were of a uniform thickness of 20 μ and were stained with hæmalum and Van Gieson's stain.

Examination of the sections (Fig. 4, 5, and 6) shows that the A-V node and the first part of the A-V bundle are involved in a well-marked acute inflammatory condition. This is evidenced by the presence of a number of focal collections of round cells and markedly congested capillaries in the node and upper half of the bundle. These cells are for the most part lymphocytes, although occasionally a few larger mononuclear cells, probably of fixed tissue origin, are seen among them. The lowest lesion to be found in the bundle is a large sized inflammatory focus situated a little to one side of the middle line of the bundle; it consists of lymphocytes, a few of the larger cells already mentioned, and also some polymorphonuclear leucocytes. It is evident that this focus is causing considerable damage to the fibres passing through it. The lower half of the bundle and its branches show nothing abnormal.

There are also a number of similar inflammatory foci with congested capillaries in the auricle, bordering on the nodal tissues.

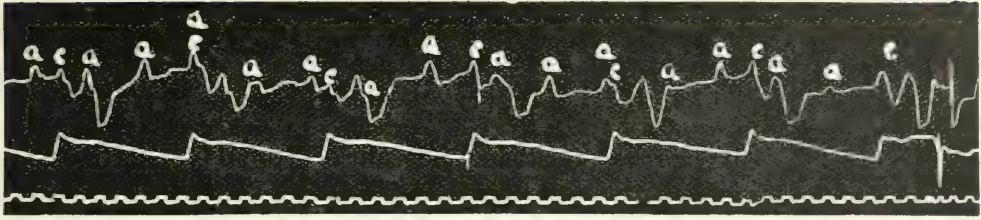


Fig. 1. A tracing from the radial artery and right jugular, showing complete heart-block. Ventricular rate, 46; auricular, about 110. The tracing was taken on the ninth day of illness. The time marker is in 1-10th sec.,

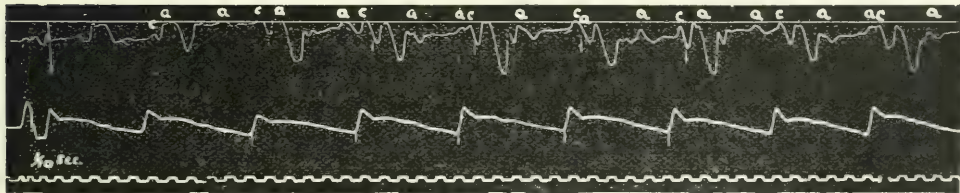


Fig. 2. A tracing showing complete heart-block. Ventricular rate, 54; auricular, about 100. The tracing was taken about nine hours before death occurred.

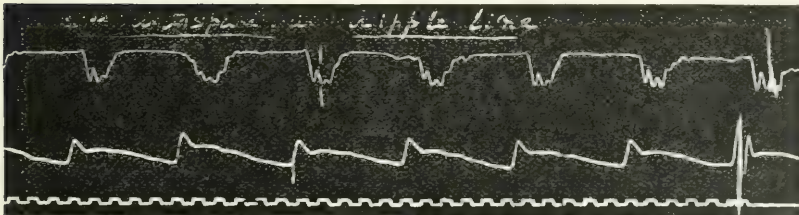


Fig. 3. A tracing from the radial artery and the fifth left intercostal space in the nipple line. The upper tracing is inverted. It shows that with each ventricular contraction there is a corresponding wave in the radial artery. The tracing was taken at the same time as the tracing in Fig. 3; that is, on the tenth day of illness,

The ventricular muscle as seen in the sections shows evidence of an interstitial myocarditis; there is a marked infiltration with inflammatory cells, mostly lymphocytes, in addition to focal collections of similar cells.

The auricular muscle also shows similar well-marked evidence of myocarditis. Here, as before, lymphocytes predominate. There is marked capillary congestion, and in places it is evident that some of the muscle fibres of the auricle have undergone fragmentation.

Clearly, the heart is the seat of a myocarditis, and the A-V node and first part of the A-V bundle have become involved in the inflammatory process. The cellular reaction throughout is chiefly lymphocytic. The lower half and the branches of the A-V bundle, as shown in the sections, are not involved in the condition.

Both vagi were examined by Donaggio's second method for demonstrating early degenerative changes, but nothing abnormal was found.

Tracings were taken on the three last days of the illness, and they all show the same condition. Unfortunately, no tracings were taken during the early stages of the illness, when the pulse was fairly frequent. It will be seen from the tracing (Fig. 1) that the auricles and ventricles are beating at different rates. The auricular rate is 110, the ventricular about 46. Now the pulse rate in complete heart-block is usually between 30 and 40, while in this case it is slightly over 46, and in Fig. 2 it is 54. From this it might be suggested that some of the auricular beats were being conducted to the ventricles, but from an examination of the tracings there is no doubt that the block is complete, the rhythm of the one being independent of the other. It is possible that the rapid action of the heart in this case is dependent upon the general toxæmia. The tracing taken from the apex beat (Fig. 3), at the same time as the tracing in Fig. 2, shows that each ventricular contraction is followed by a pulsation in the radial artery; the tracing is inverted, for it is the dilated right ventricle which is producing the so-called "apex beat." The tracings were taken with Mackenzie's clinical polygraph, with Biggs's time-marker added.

It has been shown that the heart-block may be produced experimentally by vagus stimulations, and as the patient showed signs of paralysis of the palate, it was considered advisable to examine the vagi; however, under the microscope, these showed no signs of degeneration. It must be remembered that palatal paralysis set in the day before death, whereas heart-block was established at least three days before death.

It seems to us that the block is dependent upon the numerous inflammatory foci in the auricular-ventricular node and bundle, interfering with the proper conduction of the contraction-stimulus from auricle to ventricle.

The case is of special interest in that it demonstrates that death in diphtheria, where the heart rate is slow and where signs of palatal paralysis are present, is not necessarily the result of inhibitory cardiac impulses.

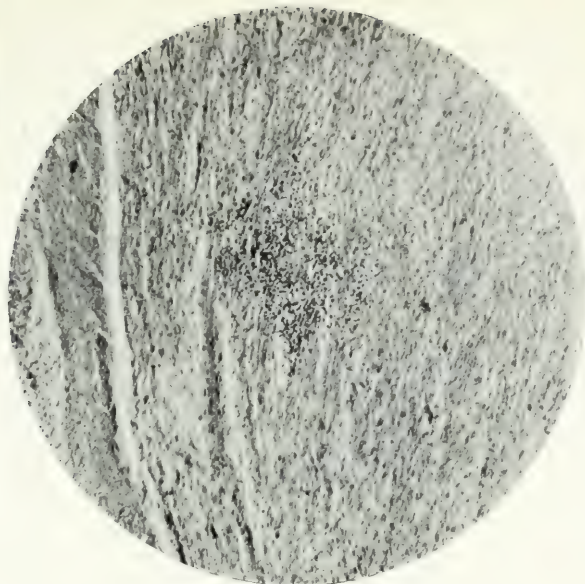


Fig. 4. Section 141. $\times 9$

FIG. 5.

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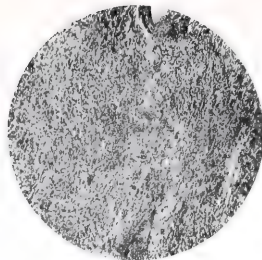


Fig. 4

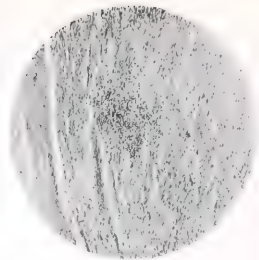


Fig. 5

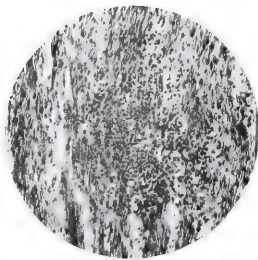


Fig. 6

SUMMARY.

A case of diphtheria in a child of 10 years is recorded, in which there was an acute inflammatory condition of the heart muscle and primitive cardiac tissue, producing complete heart-block, cardiac failure, and death.

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THE SIGNIFICANCE OF TRACINGS FROM ANEURYSMS OF THE ASCENDING AORTA.

By GEORGE DRAPER.

(From the Ayer Clinical Laboratory, Pennsylvania Hospital, Philadelphia.)

THE similarity of pressure curves taken from inside the heart or vessels and curves derived externally from their walls by appropriate receivers is so well established that every observation of the latter variety made by tracings from the exposed heart or great vessels in man is of value in studying the various events of the cardiac cycle and arterial activity.

Two classes of accidents lead to the possibility of making such direct tracings. In the first group are cases where a normal circulatory apparatus is exposed by surgical removal of part of the thoracic wall; and in the second group a practically similar result is affected by a pathological condition of the great vessels, whereby an aneurysm of the ascending aorta delivers the arterial pulsation directly at the surface. Examples of the first group are the two cases reported by v. Ziemssen and Maximowitsch⁸, and by Tigerstedt⁷; while F. Müller³ has published cases of the second. Ziemssen's and Müller's published curves do not show sufficient detail to warrant discussion at the present time. In Tigerstedt's case, however, where a large portion of the patient's sternum had been removed for sarcoma, the curves from the root of the aorta are excellent in their detail, and the author has compared them with O. Frank's intra-aortic pressure curves. In Fig. 1 the compared curves are displayed and their correspondence is striking.

In his exhaustive article on the arterial pulse Frank¹ considers that the wave marked *d* represents a bulging of the aortic cusps, as the expression of auricular activity transmitted through the ventricle. The wave *e* he believes is the "nachschwingung" or "fling" wave of the elastic diaphragm of the closed aortic valves, expressing the first effort of the ventricular systole. Its method of production he considers analogous to that of the "nachschwingung" wave following the aortic incisure *y*, and says that its length "is therefore about the same." He estimated the time measurement of the wave itself as 0.015 in. to 0.019 in., leaving a small gap between it and the main upstroke.

Whether this explanation is correct or not is still open to discussion; certainly it needs corroboration by further experimental work. Still, at

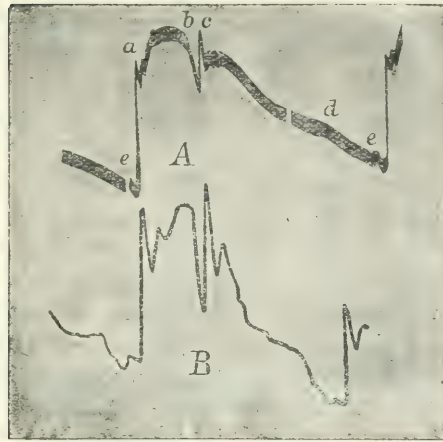


Fig. 1. A.—Intra-aortic pressure curve from dog after O. Frank. B.—Curve from root of aorta in case where sternum has been removed. (Reproduced from Tigerstedt's paper in the *Skand. Archiv f. Physiol.*) Relettered for convenience of present purpose.

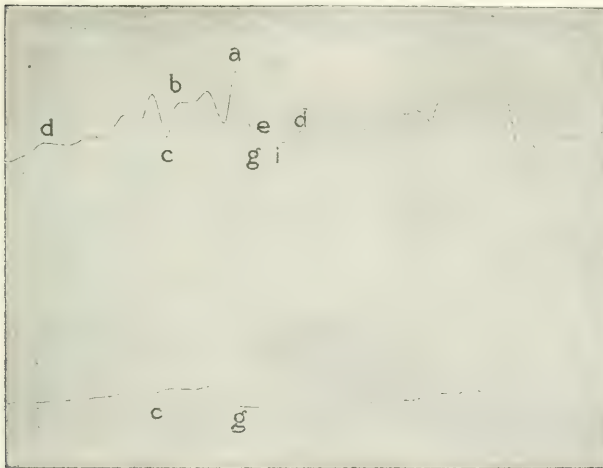


Fig. 2. Simultaneous tracings from exposed aorta and carotid artery. Read from right to left. Relettered in white. (Reproduced from Tigerstedt's paper in the *Skand. Archiv f. Physiol.*)

the present time, it is the generally accepted view, and Tigerstedt has based the interpretation of his aortic root curves upon it. In one point, however, he departs from the detail of Frank's description, and considers the *e* wave as representing the whole presphygmic period instead of a first undetermined portion of it. Both observers agree that the foot point of *e* is coincident with the onset of ventricular contraction. The work of Pachon⁴ on the "intersystole" of the heart lends further assurance to this view, and his excellent tracings indicate that the little *i* wave of the external cardiogram, which has been discussed by Piersol⁵, Robinson and Draper⁶, Jaquet and Metzner⁷, and others, is the analogue of the *e* wave at present under discussion.

To prove the correctness of his view that the end of wave *e* is synchronous with the opening of the aortic valves, Tigerstedt points out the coincidence of the *c-p* interval of the carotid curve with the moments marking the end of *e* on the one hand and the aortic incisure *y* on the other. (See Fig. 2.)* This is a questionable comparison. For the curve of intra-aortic pressure at the root of the great vessel is a curiously specialised one and is far more nearly identical with the curve of intraventricular pressure than it is with the curves of peripheral arterial pressure. And there is no question that carotid curves belong to the latter type. In the light of Frank's work it is still open to question whether the dicrotic notch of the peripheral arteries is produced by the same mechanism as that which establishes the aortic incisure. For it is not improbable that peripheral influences change the relationship of the upstroke (*c*) and dicrotic notch (*p*) of the arteriogram. Neither is this probability shaken by the fact that the *c-p* interval of the peripheral arteriogram varies at different points on the arterial tree. This question will be referred to subsequently in the discussion of the curves from the two cases now to be reported.

Case I.—L. S., coloured, age 58. Occupation, waiter.

The patient entered the Pennsylvania Hospital on February 6th, 1910, complaining of precordial pain, headache, and pain in the arms and legs. For two and a half years he has had similar difficulties and has often been treated in hospitals. At the onset of his trouble shortness of breath was marked, but this has subsided, although the other symptoms have gradually increased. About nine months ago a low swelling appeared at the precordium and grew in six months to the size of a fist. But there was no concomitant increase in the severity of his subjective symptoms. The patient makes the statement that as a result of rest in bed and the influence of a salty medicine the tumour diminished so rapidly in size that at the end of two weeks there remained only a slight prominence

* The lettering referred to in the text in this and the preceding figure is that which appears faintly and in white.

where the mass had been. No specific history could be obtained, but Wassermann reactions were very strongly suggestive.

On physical examination, absence of all signs save those of the circulatory system is striking. Examination of the anterior chest reveals a circular eminence, 10 cm. in diameter, raised perhaps 1 cm. above the surface at its centre and shading off gradually toward the margin. It lies above the nipple and nearer the mid-line, so that it is tangent below to a line just below the level of the nipple; externally, just without the nipple; above, at the second intercostal space; internally, 1.5 cm. from the mid-line. The whole mass pulsates visibly a trifle after the apex and the maximum impulse is in the centre. Marked systolic and diastolic shocks are felt.

The apex gives its maximum impulse in the sixth space, 15.5 cm. to the left of the mid-line. There is a fainter impulse in the seventh space, a little further out.

The left limit of dulness lies from the mid-line :—

Sixth space, 17.5 cm.

Fifth space, 17.0 cm.

Fourth space, 16.0 cm.

Third space, 15.0 cm.

Second space, 13.5 cm.

First space, 11.0 cm.

The upper and outer angle of dulness on the left lies a finger's breadth below the clavicle in the mid-clavicular line. The upper border then runs inward parallel to the clavicle, crosses the sternum 1.5 cm. below the notch and turns down for the right border in the first space.

Right border—

First space, 3 cm.

Second space, 4 cm.

Third space, 4 cm.

Fourth space, 3.5 cm., where lies the cardiohepatic angle.

At the apex there is a loud high-pitched to and fro murmur. The diastolic portion has the quality of the murmur of aortic insufficiency. Furthermore, the Duroziez sign is present in the femoral. The pulses are synchronous. The left is a trifle smaller than the right; both are soft and small; the vessel wall is not thickened. The systolic blood-pressure in the right arm is 121 mm. Hg.; diastolic, 90; in the left arm, systolic, 120; diastolic, 90.

With the fluroscope a large pyramidal shadow is seen having a broad base at the diaphragm on the left side, and its apex just below the sternal notch. The left border of this shadow curves outward toward the left

about at the level of the precordial eminence, and can be seen to move steadily out and in with each heart beat. No definite pulsation of the shadow can be discerned below this.

In Fig. 3 synchronous tracings from the pulsating mass, jugular vein and radial artery are shown. The *a* wave of the jugular tracing is seen

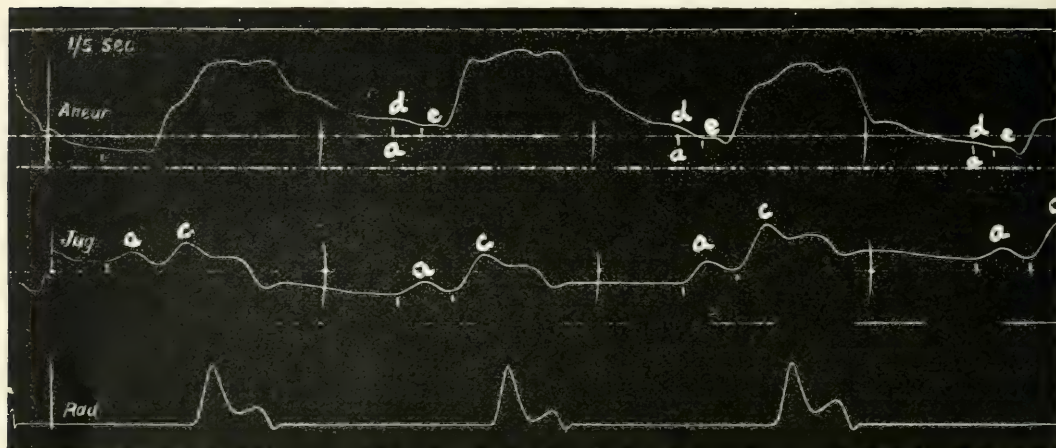


Fig. 3. L. S., 6/6/10. Simultaneous tracings from aneurysm, right jugular vein and radial artery. Case I.

to bear a constant relationship to the *d* wave of the aneurysmogram. The foot point of the jugular *c* wave is not sufficiently sharp to justify accurate marking, but its occurrence is almost synchronous with the end of the *e* wave. This point is better seen in Fig. 4, where tracings from the carotid artery and aneurysm are shown. Before passing, however, to a consideration of the relation of the carotid and aneurysm curves, it will be more satisfactory to study the simultaneous tracings from the apex and aneurysm, in order to establish the coincidence of *Vs* and the beginning of wave *e*. In Fig. 5 this is clearly shown. The correct interpretation of the cardiogram was settled by a tracing from jugular vein and apex, which it seemed unnecessary to reproduce. In this particular cardiogram no trace of the little *i* wave appears, but it will be shown later in tracings from Case II (Fig. 7).

Now, from an examination of Fig. 4, it is seen that the foot point of the carotid curve called *c* falls a trifle after the end of *e*. The separation of the two points varies considerably, and among some 35 or 40 different waves studied it measured from 0 to 0.02 sec.. In a few cases it fell a little ahead of the *F* point. These trifling differences are unquestionably due to the small element of choice which inevitably enters in the selection of

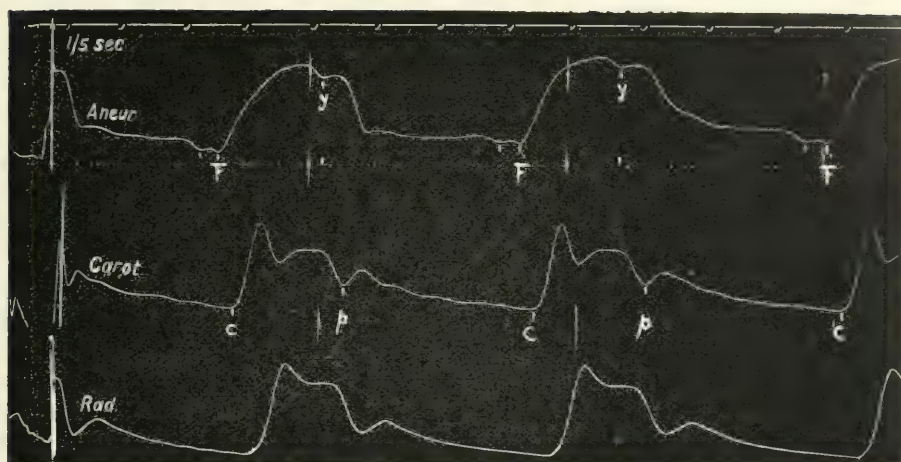


Fig. 4. L. S., 6/8/10. Simultaneous tracings from aneurysm, right carotid artery and radial artery. Case I.

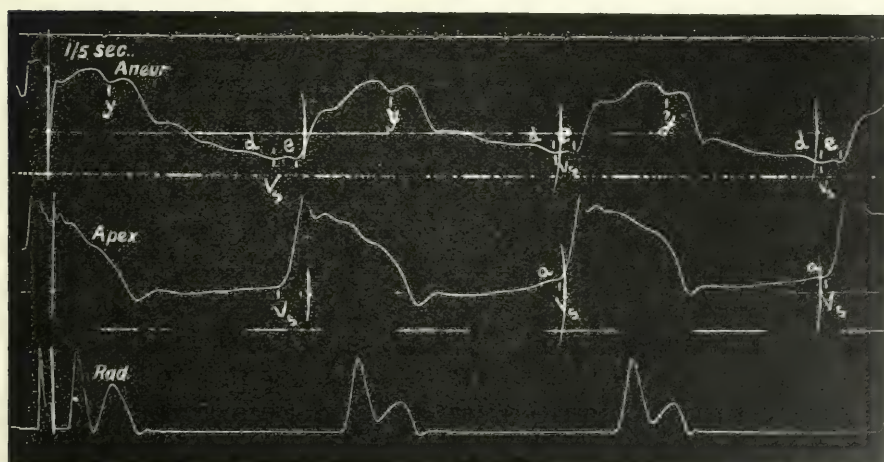


Fig. 5. L. S., 6/6/10. Simultaneous tracings from aneurysm, apex, and radial artery. Pt. on left side. Case I.

points on tracings. But the interval of time which separates the y and p points is real and of considerable length. The average duration of $F-y$ measured on 34 waves is 0.300 in.; while that of $c-p$ taken from the analogous waves is 0.336 in. In other words, the point p falls 0.036 in. later than the point y .

Case II.—J. M., white, age 43. Occupation, stevedore.

The patient entered the Pennsylvania Hospital on January 22nd, 1910, complaining of cough and pain in his shoulder. The man gave a history of moderation in the consumption of alcohol and tobacco smoking. He was accustomed to heavy physical work. His denial of syphilis was controverted by a strongly positive Wassermann reaction. Nine years before he had had rheumatism. Three months ago cough began, especially at night, and he expectorated a thick white sputum without blood stain. About one month ago pain began at the angle of his left scapula and was referred to the left shoulder and arm as far as the elbow. Sometimes the pain was dull, but usually it was sharp. During the past three months he has lost about forty pounds in weight. Physical examination reveals a much emaciated man, pale and worn-out looking, with marked depressions above and below the clavicles. Jugular and epigastric pulsations are marked. The cardiac dulness finds its upper limit at the third rib and extends outward and to the left as high as the clavicle at a point 3.5 cm. within the mid-clavicular line. On the right side dulness extends 2 cm. beyond the left sternal margin. In the third space just within the mid-clavicular line there is a well localised heaving pulsation. The impulse can be perceived almost to the sternal border. A systolic thrill and a diastolic shock are felt over the pulsation. When the patient is lying on the left side an apex impulse can be clearly made out in the seventh space between the anterior and mid-axillary lines. There is a harsh systolic murmur at the apex. It is heard over the whole precordium, but is loudest at the pulsating area in the third interspace. It can be heard in the back. The pulses are synchronous, the left of slightly greater volume than the right. The systolic blood-pressure in the right arm is 100 mm. Hg.; the diastolic, 85. Left arm: systolic, 110; diastolic, 90.

With the fluoscope two pulsating shadows are clearly visible. The lower one, well to the left, has a peculiar vermiform pulsation, while the edges of the upper shadow move steadily out and in.

In Fig. 6 simultaneous tracings from the pulsation in the third space, jugular vein and radial artery are given. Here the d and e waves appear in very marked form, and their relation to the jugular waves is seen to be the same as in *Case I*. In Fig. 7, where curves from apex and aneurysm are shown, the coincidence of V_s with the beginning of wave e is again obvious. In this cardiogram the little i wave is well seen, but its limits are not sufficiently sharp to justify measuring its length.

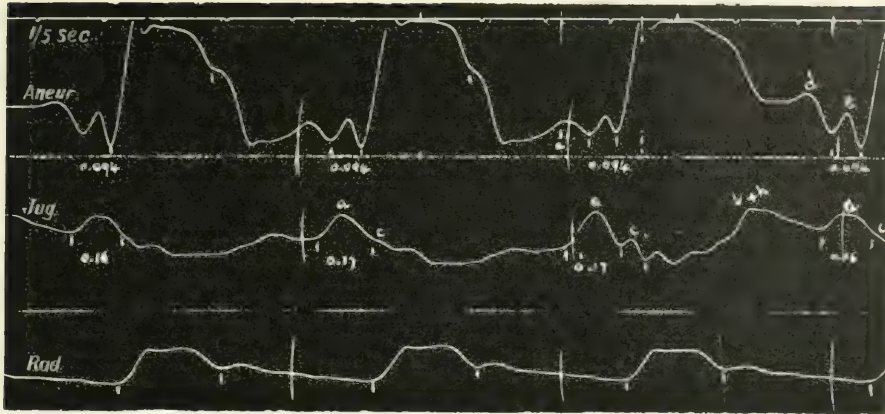


Fig. 6. J. M., 27/1/10. Simultaneous tracings from aneurysm, right jugular vein and radial artery. Case II.

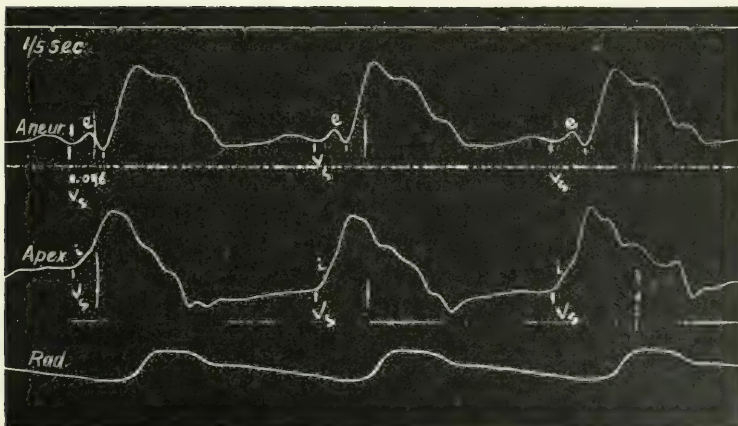


Fig. 7. J. M., 21/1/10. Simultaneous tracings from aneurysm, apex impulse and radial artery. Case II.

Unfortunately the carotid tracings from this case were so poor that measurement of the c - p interval and comparison with the F - y interval of the aneurysmogram was not possible. Nor could trustworthy measurements of the V_s -carotid time be obtained. In *Case I*, however, this last interval, was measured with comparative accuracy and found to be 0.091 in. It was hoped that an estimation of the presphygmic period could be reached in this way. But there was no means of setting a value upon the transmission time from the semilunar valves to the carotid point, because the presence of the aneurysm introduced an unknown factor.

In *Case I* the duration of the e wave was 0.07 in., so that the difference between this and the V_s -carotid time is 0.021 in.

In *Case II* the duration of e wave was 0.092 in. Tigerstedt's e wave in a normal case measured 0.051 in. This is a little below the time given by most observers for the presphygmic period. The values 0.07 in. and 0.092 in. are certainly very suggestive that the e wave represents that interval, especially so as the lower figure was found in a case where aortic insufficiency existed. Both are relatively a little longer than normal, but in each case there was a severe pathological condition which would tend to maintain the end diastolic pressure. Both cases showed a high mean diastolic pressure.

In view of these facts, and because of the sudden rise of pressure following the e wave, one is undoubtedly influenced to accept the e wave as measuring the presphygmic period.

The analogy, however, between the aneurysmal tracings and those of intra-aortic pressure exists not only in the early part of the wave, but extends throughout its whole length. The statement that the aortic incisure y occurs at the closing of the semilunar valves receives, perhaps, additional support from the tracing shown in Fig. 8 (*Case II*), taken from the epigastrium. The dip x is seen to fall at the moment when intra-aortic pressure begins to fall; in other words, when the ventricle begins to relax. At this moment the contracted ventricular wall ceases to press against the diaphragm and the little negative wave in the epigastric tracing results. At y comes the closure of the aortic valves, and the jar which produces the "nachschiwingung" wave in the aorta is transmitted to the ventricle, which is flipped downward, producing the little positive wave in the epigastrium. At z the pressure falls rapidly in the aorta, but the filling ventricle causes the positive wave in the epigastrium.

The similarity, then, between the curves of intra-aortic pressure and those from without the vessel or its aneurysmal dilatation appears sufficiently close to justify the conclusion that corresponding waves have the same origin. The temptation to speculate upon their method of production is great, and Frank's explanation of the mechanism which forms them is most suggestive, but certain doubts about the correctness of his view arise with careful study of the aneurysmograms. That the e wave is the expression of the onset of ventricular activity there can be

little question, for in both cases *Vs* is synchronous with its foot point. The origin of the *d* wave, however, is more obscure. If Frank's explanation is correct the foot points of *d* and *a* in like waves of aneurysmogram and phlebogram should be either synchronous or *d* should slightly precede *a*. This is clearly not the case. The foot point of *a* always falls well up the rising limb of *d*. Furthermore, the time elapsing between the foot points of *d* and *F* in the aneurysmal curves considerably exceeds the interval *a-c* in the jugular tracings.

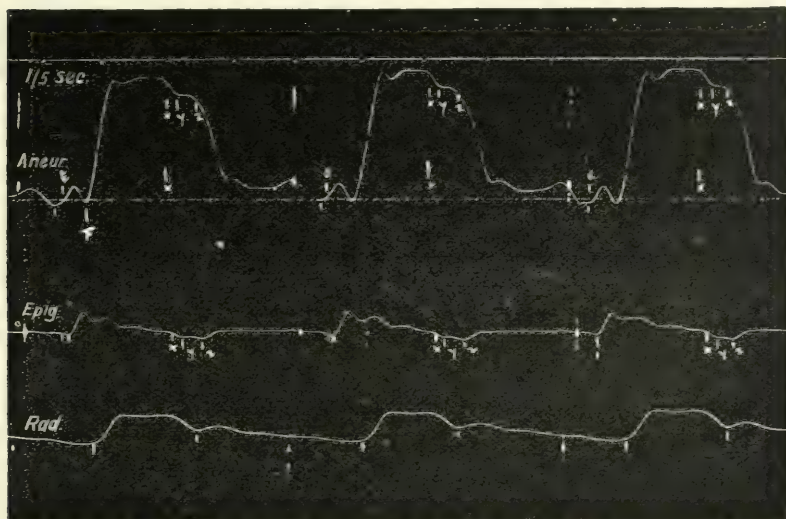


Fig. 8. J. M. Simultaneous tracings from aneurysm, epigastric pulsation and radial artery. Case II.

The doubt as to the pure auricular origin of *d* occasioned by these time relations is intensified by certain points in the form of the wave. Not in every case is there a definite upstroke, but merely a plateau in the previously descending pressure; while in each wave there is a sharp downstroke, indicating some marked negative influence.

Hypothetical explanations of the mechanism producing the wave *d* based on the aneurysmal curves might well be advanced, some in support of Frank's view and some combating it. But all are unsatisfactory. The final solution of the problem must rest in further experimental work.

Nevertheless, the general form of the aneurysmogram is apparently quite constant, and for clinical purposes sufficiently typical to be of distinct diagnostic value.

SUMMARY.

1. It is probably incorrect to compare an arteriogram of peripheral type (carotid) with the special form of pressure curve found at the root of the aorta.

2. It is not absolutely clear whether the *e* wave of aortic root curves represents the whole presphygmic period. Its beginning certainly is synchronous with the first systolic effort. The sudden rise of pressure at its latter end is suggestive of the opening of the aortic valves at that moment, but this cannot be accepted as final proof.

3. It is open to question whether the *d* wave is produced by auricular activity alone.

4. It is possible to get curves from aortic aneurysms lying low in the ascending arch which have the exact form of intra-aortic (root) pressure curves, and which may consequently be of diagnostic value.

I am much indebted to Dr. J. C. Wilson and Dr. J. Norman Henry for permission to use the clinical notes of the two cases; and to Dr. G. C. Robinson for helpful suggestions.

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OBSERVATIONS ON PULSUS ALTERNANS.

BY J. DAVENPORT WINDLE.

(Southall.)

AN alternate strong and weak beat of the pulse ascribed to variations in strength of the heart's contraction has been recognised clinically since the condition was first described by Traube, in 1872.⁴ There is a succession of high and low beats in such a way that one high pulse is regularly followed by a low one at intervals which are almost equal, but in which at times the large beat occurs a trifle prematurely.

This description of the pulse in Traube's original case conforms in essentials to those characters which are now known from experiment to result from alternating action of the heart. The current view of this phenomenon is that first advanced by Hofmann, based on experimental work.² He explained the alternating force of the beats as due to an impairment of contractility.

Alternation in force results when an extrasystole regularly succeeds each normal beat (*pulsus bigeminus*). At times this type of pulse closely simulates that of true alternation, but the weak beat occurs prematurely. In true *pulsus alternans* the rhythm is usually quite regular; if there is any difference in the pulse periods it is very slight and the longer period belongs to the stronger beat.

As met with clinically, alternating pulse may be continuous and persist for long periods of time; or it may be of brief duration and occur only under special circumstances. At times the disparity in the amplitude of alternate beats is extreme, at others slight. The factors influencing the degree of alternation are obscure. During the course of observations in this connection, made upon ten cases which have been under my care during the past year, some curious relationships were evident between the degree of alternation and extrasystoles. Some of the facts observed are briefly illustrated in the present communication.

The relationship of pulsus alternans to extrasystoles.

As a result of both experimental¹ and clinical³ observation, it is a well-established fact that, in cases in which there is a tendency to *pulsus alternans*, its onset is often the direct result of an extrasystole; hitherto

it has been found that the beats immediately succeeding the premature beat alternate in force, and that in those cases in which alternation is continuous an increase in its degree succeeds the extrasystole; but the relationship is oftentimes a more complex one than appears from a perusal of previous records.

In a large number of my tracings the sequence is not constant and considerable variation occurs both in the degree and time of onset of alternation after extrasystole. Thus, in Fig. 1 there is no alternation after the first extrasystole at A, but it is decided after the second at B.

In Fig. 2 the contrary is shown; the alternation succeeding the first premature beat at A is marked, while after the second at B it is but slight.

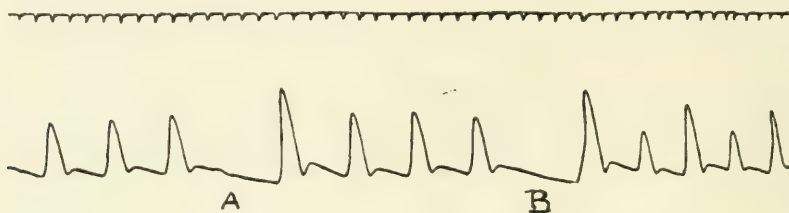


Fig. 1. No alternation succeeds the first extrasystole at A, it is decided after the second at B; there is slight quickening of the pulse during the alternating period.

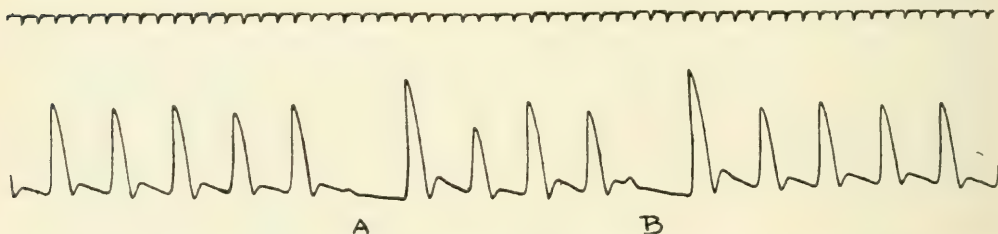


Fig. 2. Shows the opposite to Fig. 1; alternation follows the first extrasystole at A, but not the second at B; the pulse rate is constant.

Records taken from different cases with a view of determining the possible influence of respiration on the production of these anomalies have shown a close association between the position occupied by the extrasystole in the respiratory cycle and the degree of alternation in the succeeding beats.

Generally speaking, alternation is more pronounced when it follows an extrasystole occurring during inspiration, and decreased, or even abolished, when the premature beat occurs during expiration.

As a rule there are coincident changes in the rate of the pulse, which are in themselves sufficient to account for the variation; it is generally

slightly faster after an inspiratory extrasystole, slower after an expiratory one ; but this is not constant, and the rate bears no absolute relationship to the degree of alternation, for at times an *increase* in alternation is associated with slight *slowing*, a *decrease* with slight *quicken*ing of rate.

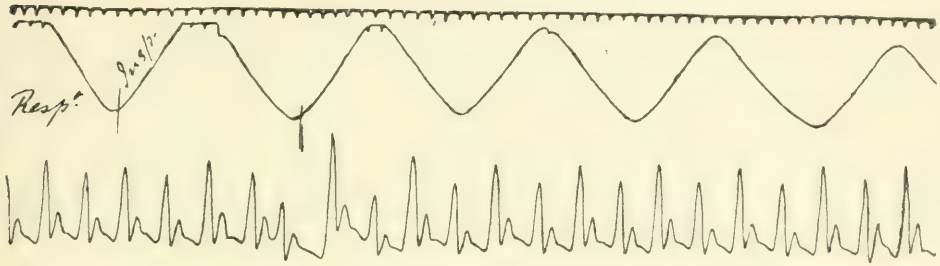


Fig. 3. The extrasystolic period falls, while thoracic pressure is high, and is succeeded by marked alternation ; there is very slight quickening in rate after the extrasystole.

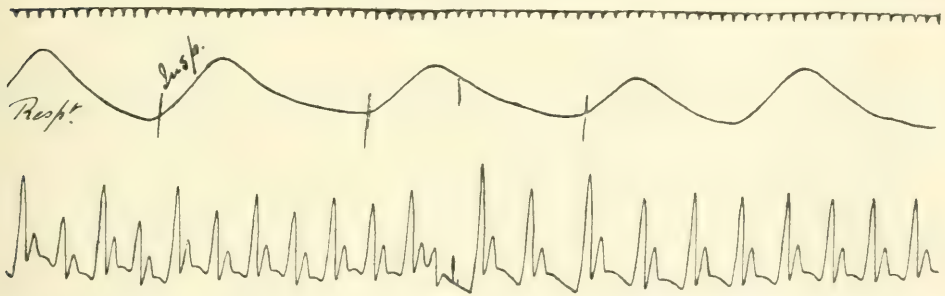


Fig. 4. The extrasystolic period occurs while thoracic pressure is low ; it is followed by a marked slowing in the pulse rate, and alternation is slight and transient.

Fig. 3 and 4, two curves taken from a single patient, are published to illustrate the variations arising when the extrasystoles fall in different phases of respiration. Thus, in Fig. 3 the extrasystole occurs when thoracic pressure is lowered, the pulse quickens, and alternation is decidedly increased. In Fig. 4 the opposite occurs—the premature beat occurs when thoracic pressure is raised, the pulse slows, and alternation is almost abolished. The figures are part of a continuous tracing, and the features shown have been fairly constant for the nine months during which the patient has been under observation. At times, and over a long tracing, a sequence of increase, decrease, and abolition of alternation occurred more or less periodically ; the onset and offset coinciding with extrasystoles, falling in the inspiratory and expiratory phases respectively.

The same facts have been in evidence in three cases in addition to the one illustrated, and I am satisfied that the relationship is not merely a coincidence.

Delayed alternation succeeding extrasystole.

Although alternation is usually the direct successor of extrasystole, this time relationship of onset is not invariable. Thus, in Fig. 5 the onset

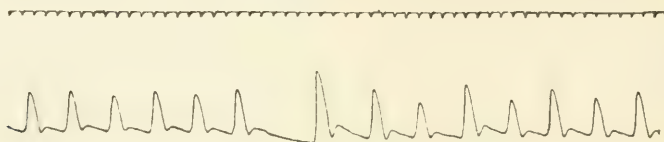


Fig. 5. $\times \frac{2}{3}$ linear. Alternation begins with the third beat after the extrasystole; the alternating beats are slightly slower than those preceding extrasystole.

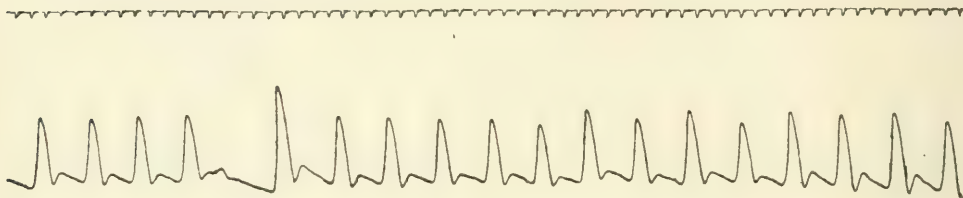


Fig. 6. $\times \frac{5}{6}$ linear. The onset of alternation occurs with the sixth post-extrasystolic beat; the alternating beats are slightly faster than those immediately before and after, but of the same rate as those preceding the extrasystole.

of alternation is delayed until the second beat after recovery, and as opposed to what usually happens, the beat following the post-extrasystolic contraction is higher than that which succeeds it. A greater degree of delay in onset is shown in Fig. 6—alternation does not begin until the sixth post-extrasystolic contraction. These variations in the time relationship of the appearance of extrasystoles and alternating heart action are not coincidental, a fact fully established by the frequency of the occurrence of the several relationships in the numerous records at my disposal.

Alternation preceding extrasystole.

Whilst it has long been recognised that a period of increased alternation commonly succeeds an extrasystole in continuous pulsus alternans, and that in cases where there is a tendency to alternation its onset may be induced by an extrasystole, the fact appears to have escaped notice that the premature beat is often immediately *preceded* by alternation in these cases, or by an increase in the degree of alternation if it is already present. (Fig. 7 and 8.) The phenomenon illustrated in these figures has been

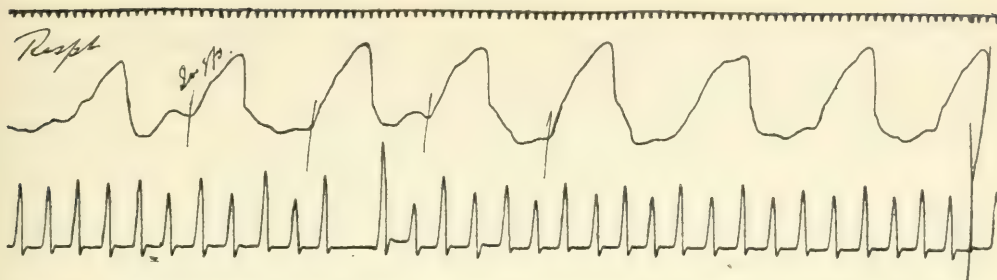


Fig. 7. Respiratory and radial curve; the onset of alternation precedes the extrasystole at X, the pulse rate of this period is slightly slower than the preceding non-alternating beats.

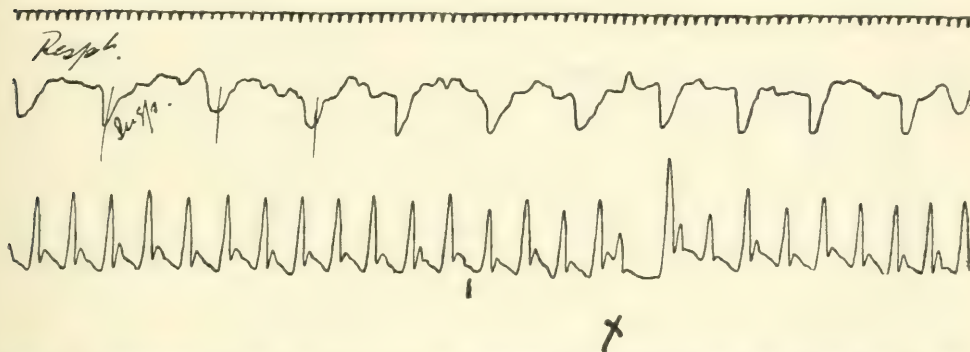


Fig. 8. Respiratory and radial curve, four alternating beats precede the extrasystole, the pulse rate is constant.

frequently observed in two other cases under my observation; it has only been in evidence when the pulse rate was not greatly above the normal, and extrasystoles occurred but occasionally.

The alternating periods are at times slightly slower, at others faster than the preceding periods. The repeated association of extrasystole and alternation suggests a common factor in their causation under certain circumstances. The alternating period preceding extrasystole rarely extends over more than one respiratory cycle; this is the only definite relationship to breathing which is evident in any of the tracings showing this phenomenon.

Fallacies in interpretation.

In radial tracings in which there is a mixture of alternation and extrasystoles, close scrutiny is required at times to distinguish the one from the other. This is particularly so when the premature beats recur rhythmically. Thus, in Fig. 9 the smallest of the grouped beats is an

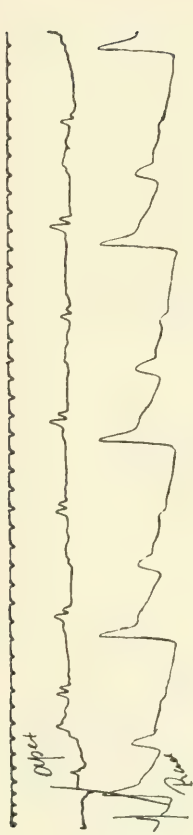


FIG. 9.

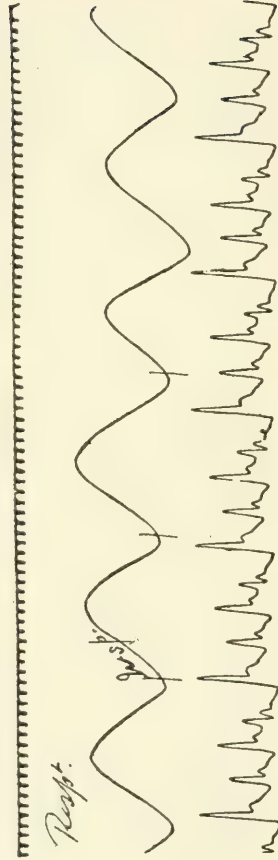


FIG. 10.

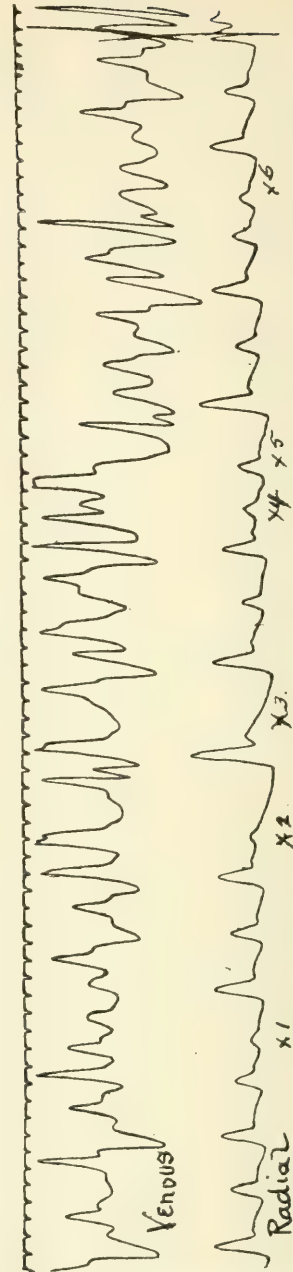


FIG. 11.

Fig. 9. $\times \frac{2}{3}$ linear. Apex and radial curve; trigeminal form of pulse, due to alternating beats regularly followed by an extrasystole.

Fig. 10. Respiration and radial curve, shows the same as Fig. 9, except that the extrasystole follows each third beat.

Fig. 11. A combination of extrasystoles and alternation; as a whole, the radial tracing bears a close resemblance to the curve of auricular fibrillation. The alternating beats succeeding the auricular extrasystole at X 1 are followed by a ventricular extrasystole at X 2, succeeding which there is a mixture of alternation and auricular extrasystoles which occur at X 3, X 4, X 5, and X 6.

extrasystole with its long pause; the big beat at recovery is followed by a true alternating beat; in turn this is succeeded by the extrasystole, and so on. The tracing was taken from a patient with pulsus alternans, during convalescence from an attack of bronchitis. The trigeminal rhythm persisted so long as the patient was quiet and at rest; after exertion the rhythm gave place to equally spaced alternating beats.

In Fig. 10 the grouping of the beats is similar to that in Fig. 9, except that the extrasystole follows each third beat.

In Fig. 11 the alternating and premature beats simulate each other closely, and the mixture gives a complex appearance to the radial tracing, which, on the whole, bears a close resemblance to a curve of auricular fibrillation.

CONCLUSIONS.

The facts in the cases observed justify these conclusions :—

- (1) In cases in which there is a tendency to pulsus alternans this is often the direct successor of an extrasystole; but this time relationship is not invariable: disparity in force may immediately precede, as well as follow, the premature beat, and, on the other hand, alternation may be delayed.
- (2) Some relationship exists between the position occupied by the extrasystole in the respiratory cycle and the degree of succeeding alternation. When the premature beat occurs when thoracic pressure is high, alternation is more prone to occur and is more decided than when the change in rhythm occurs while thoracic pressure is low.

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PERMANENT COMPLETE HEART-BLOCK.

A CASE WITH AN EXCEPTIONALLY FREQUENT VENTRICULAR RATE.

BY J. DAVENPORT WINDLE.

(Southall.)

IN the case about to be described complete dissociation of the auricular and ventricular rhythms has been permanent for at least eight months. During this period graphic records have been taken at different times and under various circumstances; complete auriculo-ventricular block has been present invariably.

The feature of interest in this connection, and in which perhaps the case is unique, is the unusually high rate of the ventricle. In complete dissociation the usual rhythm of the ventricle is a regular one of 32 per minute or thereabout. In the majority of cases of complete heart-block reported the rate has been approximately 32 per minute, and this is recognised as the usual speed of a human ventricle elaborating its own impulses. Patients in whom the rate is found to be 40 are not commonly met with; a greater frequency is quite exceptional.

In the present case the rate of the ventricle is 50 per minute; this has been the rhythm under ordinary conditions since the patient has been under observation; exceptionally it has exceeded 60, but at no time has the rate fallen below 50, except for a few beats upon rare occasions. Graphic records have shown that with these rates, and with changes in rate of the ventricle, complete dissociation persists.

History.—The patient, a man of fair social position, æt. 48, first came under observation in January, 1910. His complaint at that time was weakness and breathlessness on extra effort. He is tall, well built, and healthy looking; he has always led a regular, steady life, and has had no illness of moment up to three years ago, when he suffered from “ulceration of the stomach and vomiting,” which laid him up for some weeks. There is no history of syphilis, rheumatism, or of any other illness or accident.

The present illness dates from the early part of 1908, when he became subject to occasional fainting fits, which were ushered in by giddiness, palpitation, and breathlessness. The attacks were induced by stooping, over-exertion, or excitement. On several occasions he fell to the ground

during an attack and lost consciousness for a few seconds ; there is no history of convulsions, micturition, or biting the tongue during these attacks.

Condition.—The pulse is 50 per minute and regular in rhythm ; the wave of slow onset and well sustained. Respirations, 15. After exertion, and in raising the respirations to 25 per minute, the rate and characters of the pulse remain the same. The radial artery is thickened but not tortuous.

S.B.P. 145-150 mm.*

The heart's impulse in the sixth space is visible and palpable only in the upright position ; it is feeble, but rhythmical, and corresponds with the radial pulse. There is no precordial thrill. The limits of the heart's dulness measured from the middle line are :—L.L. $6\frac{1}{2}$ in., sixth space ; R.L. $1\frac{1}{2}$ in., fourth space ; L.U.L., third rib.

On auscultation the heart sounds are faint ; there is a very soft systolic murmur over the mitral and aortic areas partially replacing the first sound. At the apex the murmur is followed by a dull second sound, which in turn is succeeded by a soft short murmur, not always heard.

The first and second sounds are spaced ; after the second sound a third is heard after a slightly longer interval than that between the first and second sounds.† The third sound is heard only in the neighbourhood of the impulse. There is no visible jugular pulsation ; the liver is not palpable ; there is no ascites or dropsy. The lungs are clear. The urine is free from albumen. The other systems of the body present no abnormal features.

Subsequent history.—For some months past there has been an entire absence of subjective symptoms, except slight momentary giddiness on sudden change of position. No fainting fit has occurred during the past 12 months. The general health is good, and he can now undergo considerable exertion without inducing breathlessness or cardiac distress.

Special examination.

Evidence of the complete dissociation of the auricular and ventricular rhythm is furnished by the simultaneous record of the jugular and radial pulses in Fig. 1.

The rate of the auricle is 83 per minute ; that of the ventricle, as expressed in the radial curve, 50 per minute. The rhythm of *a* is regular, but its relation to *c* is constantly changing ; when *a* falls with either *c* or *v*, it is exaggerated.

Occasionally the duration of the ventricular cycles varies aperiodically ; thus, cycles of $\frac{7}{8}$ sec. occur irregularly amongst cycles of an average

* Martin's modification of the Riva-Rocci apparatus.

† The position of the third sound to the succeeding first sound is not constant, sometimes the rhythm of the sounds is $\frac{3}{4}$, at others $\frac{1}{4}$.

duration of $\frac{5.8}{5}$ sec.. There is no apparent cause for this variation; it is independent of respiration, and the block is complete. The auricular rhythm continues regular within the errors of measurement.

The same maintenance of independent rhythms is manifest in the electrocardiograms, which were taken at University College Medical School, and for which I am indebted to Dr. Th. Lewis.

Fig. 2 is an electrocardiographic curve, the leads being from the right arm and left leg taken, with the patient in the sitting posture. The rate of the auricle is 88, that of the ventricle 63 per minute. Complete dissociation of the two rhythms is present—the auricular representatives (P) fall at all times in relationship to the ventricular representatives (R and T).

Fig. 3 is an electrocardiographic curve from the right arm and left leg, the patient lying. The lower curve is that of the venous pulse taken simultaneously. The auricle is represented in the electrocardiogram by

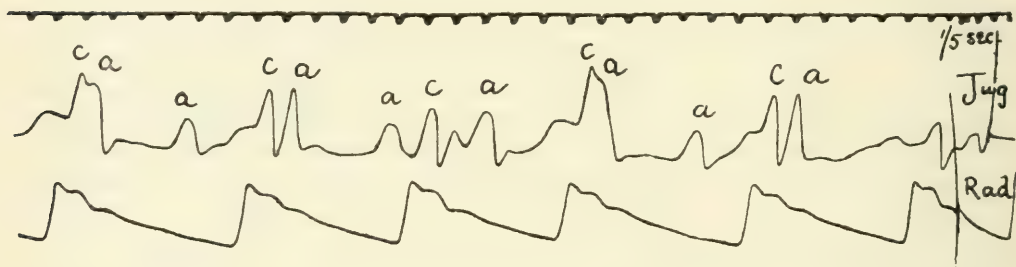


Fig. 1. Polygraphic curves showing jugular and radial tracings of patient with complete heart-block.

peaks P, in the venous curve by waves *a*. The ventricle is represented by electric peaks R and T and by jugular waves *c* and *v*. P commences approximately 0.2 sec. before *a*; R commences somewhat less than 0.2 sec. before *c*. The superimposition of P upon the ventricular representatives in the electric curve, and of *a* upon the representatives of the ventricle in the venous curve is clearly shown. The exaggeration of *a* when it falls within the limits of ventricular systole is not so clearly marked as usual. This is attributed to the fact that in this particular curve the receiver was pressed rather heavily upon the neck and considerable pulsation was transmitted from the carotid.

The following table gives the rate of the auricle and ventricle under different conditions.

The rates are calculated from electrocardiograms. Complete dissociation in rhythm persists with the changes in rate.

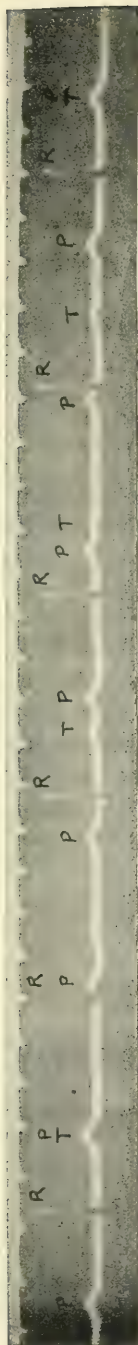


Fig. 2. $\times \frac{1}{10}$ linear. Electrocardiogram taken from the right arm and left leg; from patient exhibiting complete disassociation of auricular and ventricular rhythms. The rate of the ventricle in this figure is 63 per minute.

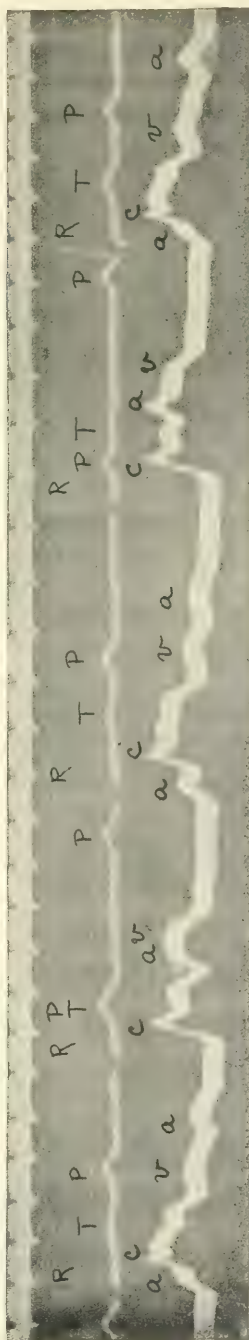


Fig. 3. $\times \frac{1}{10}$ linear. Electrocardiograph and venous curves from same patient. The relationship of the auricular representatives (P in the electrocardiograph, A in the phlebogram) to the ventricular representatives (R and T in the electric curves; c and v jugular curves) is clearly shown.

TABLE I.

OBSERVATION.	AURICULAR RATE per minute.	VENTRICULAR RATE per minute.	A-V RATIO.
(1) Examination, sitting position	88	63	1.39
(2) Lying	76	52	1.46
(3) Exercise, directly after three flights of stairs.	138	66	2.09
(4) Inhalation of Amyl Nitrite . .	138	64	2.15
(5) Under Nitrite of Amyl, Stage of Throbbing.	108	64.8	1.66

SUMMARY.

A clinical instance of permanent complete dissociation of the auricular and ventricular rhythm is described, in which the ideoventricular rate not infrequently reached 60 per minute.

AURICULAR FIBRILLATION ASSOCIATED WITH AURICULAR EXTRASYSTOLES.

BY ALBION WALTER HEWLETT.

(*Department of Internal Medicine, University of Michigan.*)

CARDIAC arrhythmias, which are characterised by an extremely irregular ventricular action and by the absence of gross auricular contractions, constitute a fairly definite group. The hypothesis that these are due to fibrillation of the auricles, originally advanced by Cushny and Edmunds,¹ has been materially strengthened by recent studies, especially those with the electrocardiograph.^{4 & 6} The following case lends support to this hypothesis because the latter permits an easy interpretation of it.

The association of auricular fibrillation and auricular extrasystoles has received comparatively little attention, although they would seem to have several features in common. Both appear to originate in an abnormally irritable condition of the auricular musculature. Stimulation of the auricles by a weak faradic current may cause a succession of auricular extrasystoles,⁷ while stimulation with a stronger current will cause fibrillation. Both are favoured by vagus stimulation and by poisoning with calcium salts or with physostigmin.^{7, 8 & 10} When the auricles are recovering from experimental fibrillation, one or more extrasystoles may occur.⁹ The clinical association of auricular extrasystoles with transient delirium cordis (auricular fibrillation) was mentioned by Hewlett,³ but was not found in five other cases studied by Fox.² It occurred in two cases reported by Lewis.⁴

In the following case we have an intimate association of auricular extrasystoles, extreme irregularity without evidence of gross auricular contractions (auricular fibrillation), and, as an intermediate type, an arrhythmia which might be interpreted either as extremely numerous and irregular auricular extrasystoles or as a coarse form of auricular fibrillation.

Mrs. V., age 31 years, entered the University Hospital on February 23rd, 1910, complaining of cardiac palpitation and of stomach trouble. As a child she had always been delicate, but with the onset of menstruation her general health became better. At 19, her perineum and cervix had been torn during childbirth. These were operated upon four years before admission and again three years before. On two occasions her right wrist had become swollen and stiff, without other symptoms of rheumatic fever.

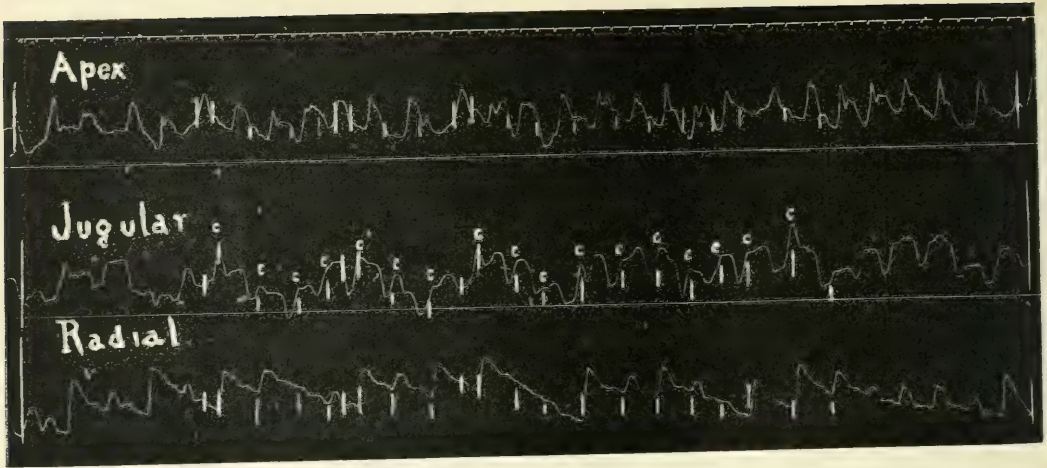


Fig. 1. Absolute irregularity of ventricles associated with positive venous pulse and absence of *a* waves (auricular fibrillation).

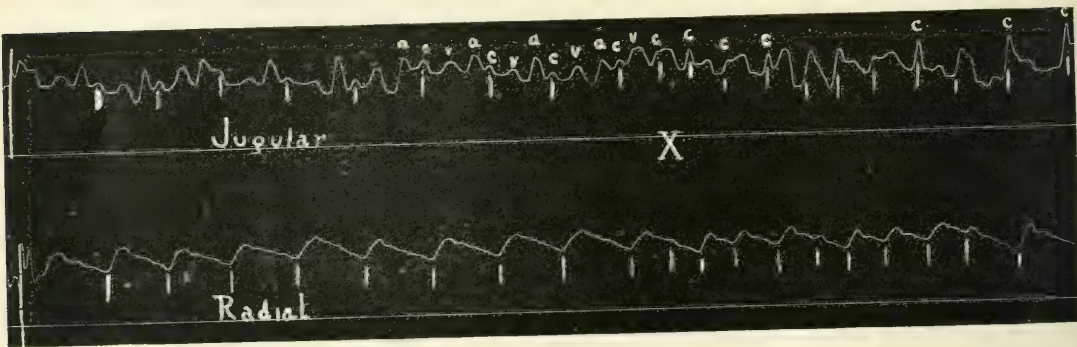


Fig. 2. Normal heart action changing at X into absolute irregularity with positive venous pulse.

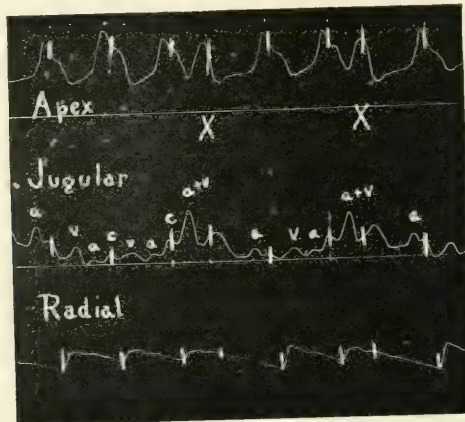


Fig. 3. Auricular extrasystoles (X).

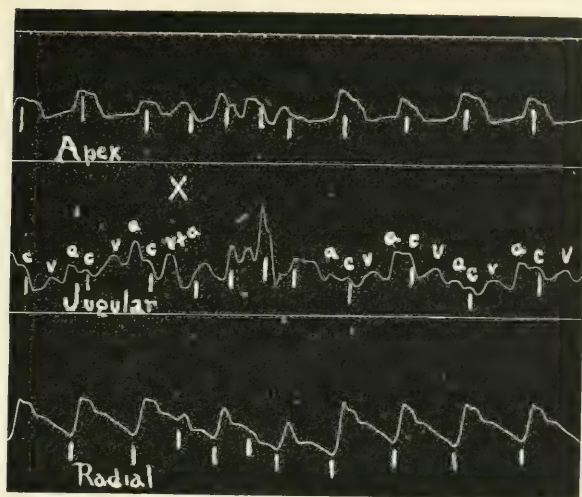


Fig. 4. Short period of irregularity beginning with an auricular extrasystole (X). During the rest of the irregularity the venous pulse is too complex for accurate analysis.

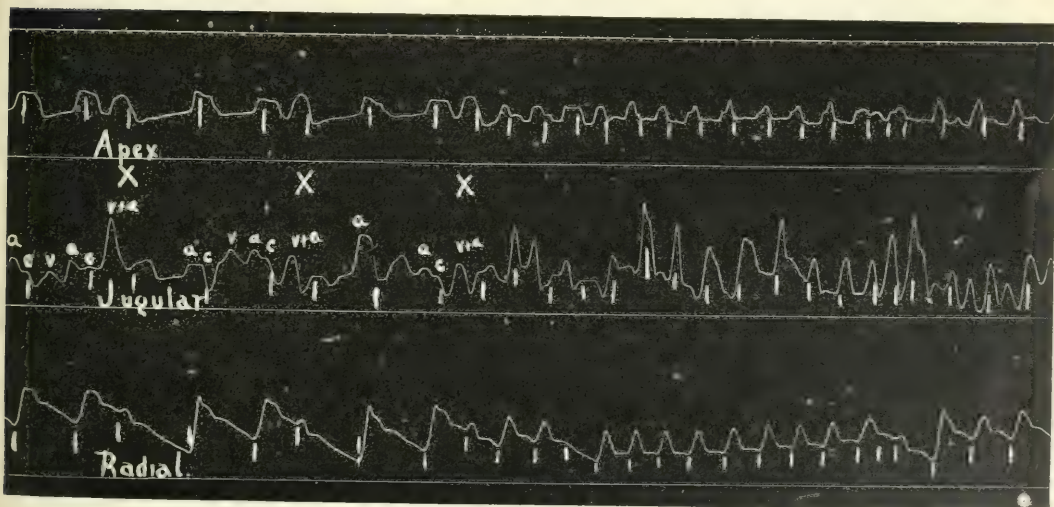


Fig. 5. A continuation of tracing shown in Fig. 4. Normal pulse with auricular extrasystoles (X) passing into marked irregularity with jugular pulse resembling that of Fig. 6. The run of regular beats suggests an auricular tachycardia.

Her heart trouble began after her first operation four years ago. She had previously had occasional pains in the left side of the chest, but had never suffered any serious cardiac difficulties. A few days after leaving her bed, however, she was seized with a paroxysm of rapid and irregular heart action, associated with sensations of suffocating and of fulness in the head. This attack passed off in about three hours. The second attack came on four weeks later, and was of the same general character. Since that time similar paroxysms have occurred at irregular intervals, but their frequency and individual duration have increased and they have rendered her a partial invalid for the past year and a half. The exciting causes of her paroxysms have not been very definite. Most of them seemed to follow exertion or heavy meals. Occasionally excitement, defæcation, or a sudden turn in bed seemed to precipitate an attack. The attacks were characterised by a rapid and irregular pulse, general nervousness, palpitation of the heart, throbbing in the head and in the great vessels, a sense of suffocation, and a slight headache. She often passed large quantities of pale urine at these times. By lying still and loosening her clothing the severity of the attacks was lessened, but they often lasted two or three days in spite of treatment. Her feet have never been swollen and she has had no marked dyspnœa on exertion, although on account of the fear of precipitating a paroxysm she has taken little exercise. In addition to her cardiac symptoms she has had some stomach trouble, apparently of a nervous character, and she has also suffered from constipation.

The examination showed a healthy looking but apprehensive young woman. Her face flushed readily and her hands were often cold and moist. The heart when regular appeared quite normal and no signs of insufficiency were apparent, except for an occasional slight cyanosis of the lips. The kidneys were easily felt. Neural examination showed stigmata of hysteria.

During several months in the hospital a great number of paroxysms of irregularity were observed and many tracings taken. During this time she improved considerably, but no reliable method of preventing her paroxysms, or of aborting them when once started, was found. Rest seemed most efficacious in preventing attacks, and on several occasions it was noticed that unusual exertion was followed within 12 hours by a paroxysm. An operation in which cervical and vaginal tears were repaired and pelvic adhesions were broken up afforded no greater relief than might be explained by the necessary rest in bed. Large doses of bromides and the correction of her constipation did not prevent attacks. During the paroxysms, morphine quieted her nervousness, but did not affect the heart action, atropin appeared to be without effect, while on some occasions injections of pilocarpin were followed by a cessation of the irregularity. The action of atropin and pilocarpin differed from what one would expect from the experiments of Winterberg, who showed that vagus stimulation favours extrasystoles and auricular fibrillation.

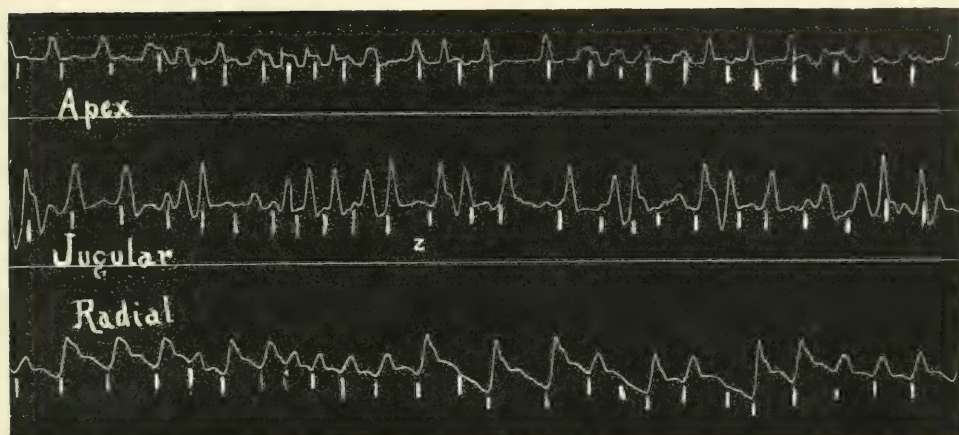


Fig. 6. Extreme irregularity with bizarre jugular pulse, due to numerous irregular auricular contractions.

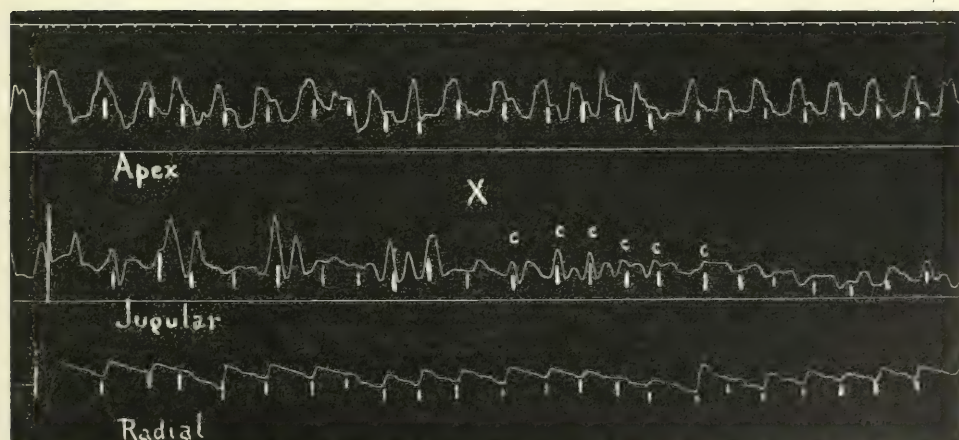


Fig. 7. Jugular pulse of type seen in Fig. 6, passing (X) into absolute irregularity with absence of auricular waves.

The venous pulse was of the normal type during her regular heart action. Three forms of arrhythmia were observed, any one of which might occur separately; not infrequently, however, one passed into another, indicating a close interrelationship. Of these arrhythmias, two are well recognised and require no extended description. The one was characterised by its extreme irregularity, a *delirium cordis*, by a positive venous pulse, and by an absence of any evidence of auricular waves upon the venous tracings. It therefore presented the features recently ascribed to auricular fibrillation. Examples are shown in Fig. 1 and 2. The latter is interesting and unusual, because it shows an abrupt transition from the normal to the positive venous pulse of auricular fibrillation. The second type of irregularity was that due to auricular extrasystoles. At times these occurred singly or in rotation, and they could then be recognised by palpation or auscultation, and the interpretation of tracings, such as Fig. 3, presented no particular difficulty. Occasionally, however, as in Fig. 4, a short series of rapid ventricular beats occurred. The first of the series seemed due to an auricular extrasystole, but later the venous waves became so complex that an accurate interpretation was impossible.

Such irregularities show transitions (Fig. 5) to the final type of arrhythmia obtained from this patient. This was characterised by extreme ventricular irregularity and by a bizarre jugular pulse, which did not permit detailed analysis. Examples of this are shown in the latter half of Fig. 5, in the whole of Fig. 6, and in the first part of Fig. 7. The numerous high waves that occurred in the jugular pulse curve at irregular intervals bore no definite relation either to the radial pulse or to the apex beats. We have been able to find no reasonable explanation for these waves other than that they are due to irregular auricular contractions, many of which coincide with ventricular contractions. The condition is complex and not easily analysed. Two explanations of this arrhythmia suggest themselves. The first is that it is due to numerous and irregular auricular extrasystoles; the second that the auricles are fibrillating, but in such a coarse manner as to produce large waves on the jugular pulse. Rihl⁵ has studied the venous pulse in one case of experimental auricular fibrillation following vagus stimulation, and has shown that it resembles the venous pulse produced by ventricular contractions when the auricles are motionless. He admits the possibility that coarse fibrillatory movements of the auricles might produce venous waves, especially during the longer ventricular pauses. Lewis¹ has shown such waves on venous tracings during experimental fibrillation, though these were much smaller than those obtained from our patient. Unpublished experiments performed by the author and by Dr. Ernest Dozier in the physiological laboratory of the Cooper Medical College in 1907 also indicated that auricular fibrillation might or might not affect the venous pulse. When auricular fibrillation was produced by faradic stimulation of the auricles, these often contracted to a smaller size and fibrillated coarsely, producing waves on the jugular

pulse. To what extent this might occur is shown in Fig. 8. If, however, the cut end of the vagus was stimulated at the same time as the auricles, the latter were usually dilated, the fibrillations were much finer, and the venous pulse might show no waves of auricular origin.

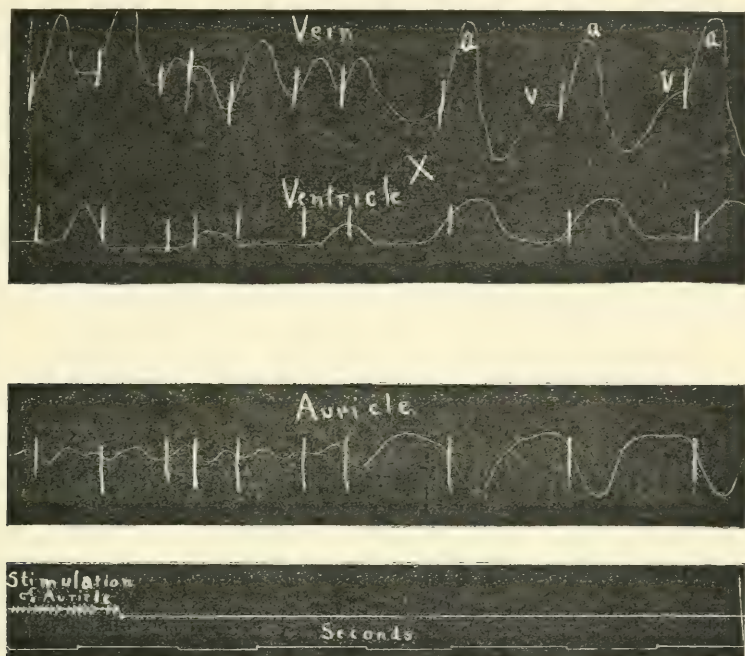


Fig. 8. $\times \frac{2}{3}$ linear. Venous pulse during coarse fibrillation of the auricles of a dog's heart produced by faradic stimulation. (Experiment performed with Dr. Dozier.) In the myocardiograph tracings the downstrokes represent auricular and ventricular systoles. The venous pulse was obtained from the right innominate vein by a canula method. The venous waves correspond fairly closely to the recorded auricular systoles and the discrepancies indicate that some waves affected the venous pulse without involving the portion of the auricle included by the myocardiograph, and *vice versa*. No relation is apparent between venous pulse and ventricular contractions. At (X) normal rhythm is established.

In the interpretation of the tracings from our patient it is not essential whether we regard the large waves as due to numerous and irregular auricular extrasystoles or as due to a coarse form of auricular fibrillation, for in either case we have a type of irregularity intermediate between ordinary auricular extrasystoles and the finer form of auricular fibrillation. Transitions to the former are shown in Fig. 5, and to the latter in Fig. 7. A coarse fibrillation is suggested by the facts that the ventricular contractions do not follow the large waves by any fixed interval and that the period between the two is sometimes so long that it seems improbable that the stimulus for the ventricular contraction has come from the auricular contraction producing the large wave (Fig. 6, z). In such cases the ventricles probably

either contract spontaneously or they follow auricular contractions which do not appear on the venous pulse. The latter condition is what one might expect in coarse fibrillation.

CONCLUSIONS.

In the present case we are probably dealing with conditions very similar to those that can be produced experimentally by electric stimulation of the auricles, and we have a combination of (1) isolated auricular extrasystoles, (2) numerous and irregular auricular extrasystoles or a coarse form of auricular fibrillation, and (3) fine auricular fibrillations which produce few, if any, venous waves.

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SURVIVAL OF ENGRAFTED TISSUES.—III. BLOOD-VESSELS.*

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THE subject of blood-vessel reunion is not only of pathological interest, especially from the standpoint of experimental arterio-sclerosis, but of more general biological interest and surgical interest as well. At the present time only the results will be presented. The discussion will be undertaken at a later date.

METHODS.

Healthy animals under ether anæsthesia were used for the most part. The blood-vessels were rapidly exposed and freed from surrounding tissues. As a rule, ordinary serrefines were employed for hæmostasis. Excess of blood was removed by stripping the vessels gently between the thumb and forefinger and sponging with ordinary gauze or cotton and gauze sponges. In the later experiments salt solution when used at all was used very sparingly. Paraffin oil was employed upon the thread and sparingly on the blood-vessels. Cambric needles, ranging in size from No. 12 to 16, and the best quality of fine silk or human hair were used. The walls of the vessels were united and the intimal surfaces closely approximated, and thus fixed by continuous stitches, which penetrated all the vascular coats; *the intima was especially included.*

Care was taken to avoid the introduction of any connective tissue into the lumen of the vessel, either between the cut edges or through the needle holes along with the thread. Oil serves an important function in preventing the last accident. When hair is employed the tendency for the loose connective tissue to adhere to the ligature is greatly lessened. After completing the union, any available adventitial sheath was drawn over the line of anastomosis and held in place with a gauze sponge. The hæmostatic clamps were then removed and the circulation established. For one to two minutes the sponge was held rather firmly

* The first paper of this series was on ovaries and testicles, and appeared in the *Journal of Experimental Medicine*, 1910, XII, 269; the second dealt with thyroid and renal apparatus, and appeared in the *Journal of the American Medical Association*, 1910, LIV, 831. The results herein reported were presented before the Section on Pathology and Physiology of the American Medical Association at Saint Louis, June, 1910.

on the line of union and then cautiously removed. As a rule the vessel would then present a smooth and dry external surface. But in case of bleeding, the forefinger was placed beneath the line of anastomosis and the vessel raised and compressed, and the leak stopped with one or more stitches. The wound was wiped out with a sponge slightly moistened with 0.9 per cent. sodium chloride solution. The muscles were brought together by a continuous cat-gut suture, the subcutaneous tissues by another, and the skin by a third. The skin was sponged with alcohol and the dry wound generously dressed with boric acid, absorbent cotton, plain cotton, a roller bandage, and lastly a tailed bandage of heavy muslin (unbleached sheeting), the ends of the latter being so tied that it formed a snug jacket.

The animal was then placed in the hospital in a separate room provided with a raised screen bottom and drain. Generally, and within an hour or two, such animals showed little or no inconvenience from the operation. The wounds remained dry and healed rapidly.

COMBINATIONS AND RESULTS.

It is evident that many different combinations of blood-vessels are possible, ranging from simple suture of the ends of a divided arterial or venous trunk to the engrafting of a segment of vein between the ends of a divided artery, with reversal of the direction of the circulation in the venous segment.¹ But in this place it is my purpose to describe only such combinations as have yielded results that contribute definite knowledge of the structural character of blood-vessels after such operations.

The simplest class of operation, reunion of divided arteries or veins, appears to produce no structural alteration of note, beyond the traumatic effects in the immediate vicinity of the line of suture (Fig. 2, 3, 3a, and 3b).

Protocol Dog 21.

May 7th, 1908.—Young adult, black, male. Weight 6.3 kilog.. Under ether anæsthesia both common carotid arteries were divided and the central end of the left was anastomosed to the peripheral end of the right; twenty-five stitches and twelve minutes were required for the operation. The other ends of the arteries were permanently ligatured. The right external jugular vein was divided and reunited; twenty stitches and ten minutes were required. The dog made an uneventful recovery.

May 17th.—Circulation appeared to be good through both anastomoses.

May 27th.—The animal was etherized; after exposing the vessels and demonstrating that the circulation was excellent, the specimens were removed (Fig. 2).

Protocol Dog 6.

May 29th, 1907.—Black bull-poodle, male. Under ether anæsthesia the ends of both common carotid arteries were divided and tied. A lateral anastomosis near the central end of the left and near the peripheral end of the right was instituted.

December 19th, 1907.—The animal was etherized; the circulation through the anastomosis was seen to be excellent. The specimen was removed. On longitudinal section, the intima was smooth and glistening; the stitches were seen beneath it (Fig. 3a). The lumen was unobstructed.

The results of more complex combinations, the interposition of an arterial segment between the ends of a divided artery and the interposition of a venous segment between the ends of a divided artery are illustrated by Fig. 1, 4, and 5, and are described below.

Protocol Dog 18.

April 24th, 1908.—Old black and brown male cur. Weight 9 kilog.. Purulent discharge from nose. Etherized.

Removed segments of the left external jugular vein, the right common carotid and left common carotid arteries. Inserted a segment of the left external jugular vein between the cut ends of the right common carotid artery. Transplanted the segment of the right common carotid artery between the ends of the left common carotid artery.

April 28th, p.m.—The dog was very weak, and there was much discharge from the nose. He would not eat or drink. The bowels were loose.

April 29th, a.m.—Dog died.

Post-mortem examination.—The wound was dry and well healed. The deep neck structures were in excellent condition. The right common carotid artery and the venous segment were in good condition, as were also the left common carotid artery and the segment of the right common carotid artery (Fig. 4). Opened thorax. Advanced purulent pericarditis with pleural effusion were present. A large quantity of purulent liquid was found in the pericardial and pleural cavities. The pericardium was enormously thickened.

Protocol Dog 20.

April 29th, 1908.—Medium-sized adult dog. The common carotid arteries were exposed under ether anæsthesia. A small segment from the left was removed and preserved. A segment from the right was removed and interposed between the ends of the left. The right external jugular vein was exposed and a segment removed and interposed between the ends of the right common carotid artery. The normal direction of the circulation in both segments was preserved. *Very little* sodium chloride

(0.9 per cent.) solution and paraffin oil were used. The circulation through both segments was excellent. The dog made an uneventful recovery.

May 12th.—The circulation on both sides was excellent.

May 21st.—The circulation on both sides was excellent.

May 27th.—The carotid arteries were exposed and a very active circulation through the segments was demonstrated. The specimens were removed.

The arterial segments showed no marked changes except at the lines of anastomoses (Fig. 5, A, A, and Fig. 1, A). With the venous segment the case was quite different, especially after some weeks (Fig. 5, B and 1, B) when it showed not only moderate and somewhat irregular thickening, but marked histological alteration.

Macroscopical examination.—The venous segment was of about the same size or perhaps a little larger than when last seen. Externally, it was fibrous and red, particularly in certain areas. Small circular ridges marked the points of anastomoses. On longitudinal section it collapsed. Two sets of valves which appeared normal were present, one set being near the distal end of the segment. In physical character the wall was pliable but somewhat thickened, especially in the inter-valvular regions. In the thicker areas it was opaque, while behind the valve cusps it was quite transparent and showed little if any thickening. The thickened areas were red and were richly supplied with blood-vessels, while the thinner and more transparent areas showed slight or no evidence of such vessels. The intima was smooth and glistening throughout and was continuous with that of the artery at either end. The stitches could be seen at the line of anastomosis, but they were buried by a covering of newly-formed tissue in all respects similar to the surrounding intimal tissue. The surface presented a somewhat yellowish coloration. The mouths of a number of small venous branches, which were ligatured at the time of the operation, appeared.

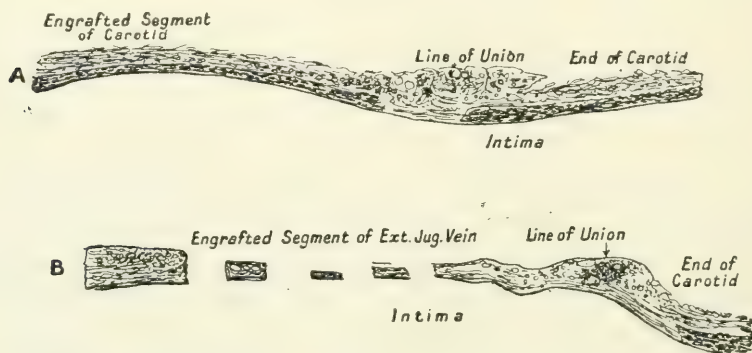


Fig. 1. Dog 20.—A. Artery on artery. B. Vein on vein. Magnified, projected and drawn.

Microscopical examination.—Besides an irregular thickening, the most striking features were evidences of œdema and retrogressive changes of a hyaline character; complete absence of muscle fibres; numerous newly-formed blood-vessels in the outer coats, most marked in the thicker areas; masses of interstitial (extra-vascular) blood in the outer coats of the thicker areas; and a very pronounced perivascular (periadventitial) fibrosis. At the lines of anastomoses the appearance was modified by the traumatic effects. The embedded ligature was separated from the lumen by what appeared to be the organised remains of a thin, band-like thrombus or fibrinous deposit which presented a smooth surface and was composed of flattened cells with elongated nuclei (Baumgarten type of cells). The superficial cells, though not identical in appearance with those of normal intimal endothelium, resembled them in general character and arrangement. Elastic fibres, which were fairly abundant, were chiefly of the coarser variety. For the most part they were longitudinally arranged and occurred in the inner coats, and especially in what corresponded to the middle coat normally. The circularly disposed fibres were situated internally to the longitudinal ones.

Hetero-transplantation.—A segment of rabbit's aorta interposed between the ends of a divided artery of a dog, though performing an adequate function as regards the transmission of blood, shows marked changes (Fig. 6). A similar result was observed in an aortic segment from a cat similarly engrafted into a dog.²

Protocol Dog 2.

May 15th, 1907.—Young adult, female, in fair condition. Weight about 11·3 kilogr.. Large double goitre. A segment of the left common carotid artery, 0·5 cm. long, was removed and a segment of the abdominal aorta from a 3000 gram white male rabbit was interposed, the segment being about 2·5 cm. long. The arteries of the dog were considerably enlarged. The diameter of the common carotid artery was more than twice that of engrafted aortic segment. The circulation was restored through the segment about one and one-half hours after its removal from the rabbit.

June 15th, 1907.—Under ether anæsthesia the wound was reopened, and the segment of aorta was found to have the same diameter as the carotid artery, and to be somewhat longer than at time of transplantation. The circulation was excellent.

December, 1907.—The transplanted segment was removed. The circulation at the time was excellent.

Macroscopically, the segment was much enlarged. It was greyish in colour and densely fibrous in appearance. It was quite rigid and on longitudinal section, which procedure indicated a considerable degree of calcification, the walls showed no tendency to collapse. Separation of the

longitudinal edges was resisted by the rigidity of the walls, and on forcing the artery open rupture of the intimal surface occurred at the point of greatest extension. Except for this, the intimal surface was smooth and glistening, though presenting several cup-like irregularities, which were neither very abrupt nor deep. The intimal surfaces of the segment and of the artery at either end were continuous and smooth. The wall was somewhat irregularly transparent. The lumen was much larger than that of the artery.

Microscopically, the wall varied in thickness from about three to six times its thickness at the time of transplantation. The intimal surface was smooth and continuous with that of the artery. The tissues were stained irregularly and diffusely (hæmatoxylin-eosin). They were densely fibrous and showed retrogressive changes of a hyaline character and areas of calcification. No muscle was present. The suture material was deeply buried at the lines of anastomoses. From near this point (line of anastomosis) the ends of the artery appear normal.

A segment of vena cava was taken from a dog and preserved and fixed for 60 days in 2.5 per cent. formalin in 0.9 per cent. sodium chloride. It was treated with dilute ammonia, dehydrated in absolute alcohol and impregnated with paraffin oil, and then engrafted between the ends of a divided common carotid artery of another dog. Excellent functional reunion was observed. Twenty-three days after the operation direct examination (under anæsthesia) revealed an excellent circulation, confirming the previous clinical examination, and the segment, though it showed some alteration, was performing its function well.³ More than 27 months have elapsed and the segment is still performing its circulatory function satisfactorily. Histological studies have not been made. According to Levin and Larkin, who reported similar experiments, considerable structural alteration should occur.⁴ But since their longest observation, uncomplicated by occluding thrombosis, was of but 11 days' duration and was complicated by infection, the observation of ultimate structural results are still wanting. And their criticism of Carrel's views regarding the results of hetero-transplantations and of similar transplantations of tissues preserved in cold storage, though warranted from a theoretical standpoint (as I pointed out some years ago¹), are not fully borne out by their experiments.

Simple arterio-venous anastomosis, as in arterialization and reversal of the blood stream in the distal end of a vein by uniting it with the central end of an artery (Fig. 7) is followed by marked structural changes in the vein.¹

Protocol Dog 4.

June 15th, 1907.—Young adult, female. Good condition. Weight 11.3 kilos.. Presents a large symmetrical and double goitre.

Under ether, the circulation was reversed in the right internal thyroid vein by dividing and anastomosing its peripheral end to the central end of the divided right common carotid artery. The subsequent circulation was excellent. The thyroid immediately became engorged and showed strong pulsatory expansion and contraction and commencing œdema. The wound healed rapidly, and the animal remained in good condition.

May 12th, 1908.—The blood-vessel was re-exposed under ether and removed.

Macroscopically, the vein was somewhat larger in diameter, and the walls more rigid and thicker than normally. In colour it was pale and greyish. No marked vascularity was noted. Upon longitudinal section it did not collapse. The intima was smooth and glistening and continuous with that of the artery. The actual line of blending of the arterial and venous tissues could only be detected by close examination. The wall appeared to be abnormally transparent.

Microscopically, the wall was thickened. The intima was smooth and beneath it there was muscular tissue, though not an abundance of it. The remainder of the wall was dense, hyaline and fibrous in character, and very few nutrient blood-vessels could be seen. The fibrosis was most marked external to the middle coat. In the latter was a moderate number of elastic fibres, chiefly of the longitudinal coarser type.

SUMMARY.

1. Union of arteries or of veins either end to end or by lateral openings, by through and through suturing as described, is not followed by structural alterations of note in the vessels themselves, excepting for the insignificant traumatic effects at the line of union.

2. In veins in which the circulation is changed to arterial and reversed, thickening is observed. Muscle tissue is present after many months.

3. Eck's fistula in cats is not followed by vascular changes of note (Fig. 3*b*). The observation that cats showed absolutely no clinical abnormalities even on an exclusively meat diet during one and two years respectively is of additional interest. This is at variance with the statement commonly made concerning dogs; the latter are said to generally show symptoms similar to ammonia intoxication (convulsions) which are supposed to be due to the incomplete conversion of the nitrogenous end-products of protein metabolism into urea, etc.

4. A segment of dog's carotid artery removed and quickly engrafted between the cut ends of the other common carotid artery, shows very little microscopic change after four weeks, excepting for some thickening at the line of anastomosis.

5. A segment of dog's external jugular vein removed and quickly engrafted between the ends of a common carotid artery, the normal direction of blood flow being preserved, showed moderate thickening and indications of degeneration after four weeks, particularly of the muscular tissue, which was entirely missing. A similar segment showed much less change after five days.

6. A segment of dog's external jugular vein removed and soaked in salt solution and engrafted between the ends of a common carotid artery, showed very much greater thickening at the end of two weeks than in the result above cited, but muscular tissue was present.

7. A segment of rabbit's aorta engrafted between the cut ends of a dog's common carotid artery showed great enlargement and marked thickening and hardening (calcification) of the walls after seven months. Muscular tissue was absent.

8. A segment of dog's vena cava preserved for 60 days in 2.5 per cent. formalin, washed in dilute ammonia, dehydrated with absolute alcohol, impregnated with paraffin oil, and transplanted between the ends of a common carotid artery of a bitch, showed an active circulation three weeks after the operation, but marked enlargement was present. At the end of more than 27 months the circulation is still good.

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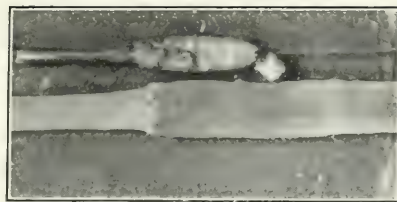


Fig. 3.

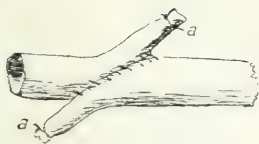


Fig. 3a.

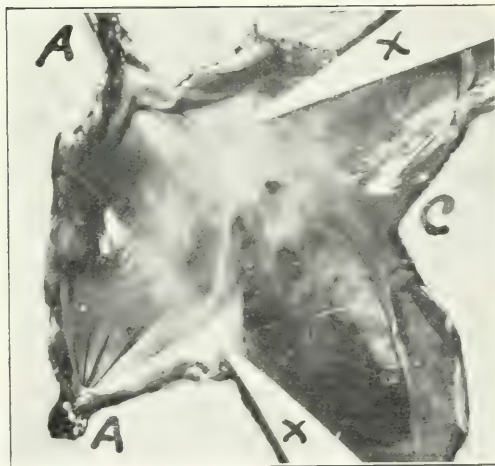


Fig. 35.



Fig. 2

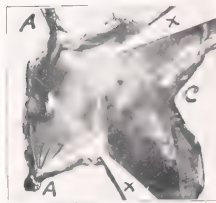
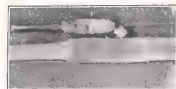


Fig. 3



Fig. 4

g. 4. Dog 18.—A. Seg
vein on carotid artery
which a half circular p
small lamellar white fil

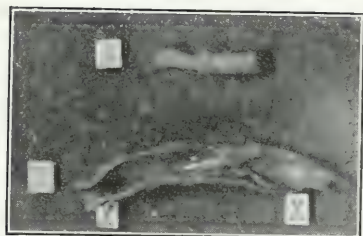


Fig. 6.

g. 5. Dog 20.—A. Seg
jugular vein on carotid
surfaces of segments.
X, X indicates lines o

g. 6. Dog 2.—Transplac
of transplantation, as
comparison. B. Seve
irregular owing to a s

g. 7. Dog 34.—April 10
peripheral end left inte
1909. A indicates line

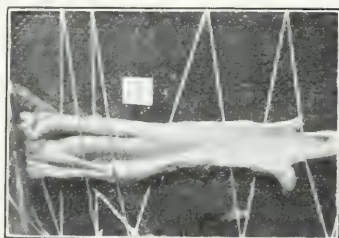


Fig. 7.

Fig. 1. *Arteriovenous anastomosis.* B. Segment of regular artery. A. Venous end of anastomosis. C. Segment of regular vein. D. Venous end of anastomosis. E. Endarterectomy. F. Endarterectomy. G. Endarterectomy.

Fig. 2. *Arteriovenous anastomosis.* B. Segment of extended artery. A. Venous end of anastomosis. C. End of anastomosis. D. End of anastomosis. E. End of anastomosis. F. End of anastomosis. G. End of anastomosis.

Fig. 3. *Arteriovenous anastomosis.* A. Distal artery. B. Venous end of anastomosis. C. End of anastomosis. D. End of anastomosis. E. End of anastomosis. F. End of anastomosis. G. End of anastomosis.

Fig. 4. *Arteriovenous anastomosis.* A. Distal artery. B. Venous end of anastomosis. C. End of anastomosis. D. End of anastomosis. E. End of anastomosis. F. End of anastomosis. G. End of anastomosis.



Fig. 1

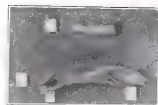


Fig. 2



Fig. 3



Fig. 4

PAROXYSMAL TACHYCARDIA, ACCOMPANIED BY THE VENTRICULAR FORM OF VENOUS PULSE.

By THOMAS LEWIS.

(*From University College Hospital Medical School.*)*

THE ventricular form of jugular pulse may be defined as a type of venous pulsation, in which no constant and prominent waves present themselves, at such periods as represent the diastoles of the ventricle.

It has been regarded as significant of the absence of auricular contraction during the diastole of the heart ; but it is now known that it may be found where the auricular systole, falling at its proper instant during the cycle, fails to affect the venous pressure appreciably or at all.² The events occurring in the auricle when the venous pulse is of the ventricular form cannot be gauged from this type of pulsation itself ; for when it is present the mechanism of the auricle may be one of the following forms :—

1. Contraction, at the normal instant in the cycle, of an auricle which is in a state of distension, or the power of which is damaged in some other fashion.
2. Fibrillation of the auricle.
3. Simultaneous contraction of auricle and ventricle.

In a previous communication² the relationships of such abnormal auricular activities were discussed, and certain conclusions were formed in regard to them.

At that time it seemed clear that auricular fibrillation is never accompanied by regularity of the ventricle, except when it is complicated by auriculo-ventricular heart-block ; and it appeared reasonable to assume that, where the ventricular form of venous pulse is present *and the pulse is regular* and of normal or increased rate, the auricle is not in a state of fibrillation.

The ventricular form of phebogram, associated with *regularity* of the pulse, may conveniently be grouped under three headings :—

- (a) Where the pulse is slow and auricular fibrillation and heart-block are present.

* An investigation carried out under the tenure of a Beit Memorial Research Fellowship.

(b) Where the auricle is distended and its contractions are ineffective in raising venous pressure; the pulse being of normal or somewhat increased rate.

(c) Where the pulse is greatly increased.

It is under the last heading that a by no means uncommon type of paroxysmal tachycardia falls, of which a number of polygraphic curves have been obtained (Mackenzie,³ Hewlett,¹ Lewis²). But the interpretation of the mechanism of the heart-beat in such cases has never been more than speculative, for hitherto no electrocardiograms have been won. It has been suggested that paroxysms of *regular* tachycardia, accompanied by the ventricular type of venous pulse, may arise, as a consequence of simultaneous auricular and ventricular systole, either in response to impulses originating in the junctional tissues,⁶ or as a result of altered conduction, and the coincidence of an auricular systole with the ventricular systole of a preceding cycle⁷; or, lastly, as the outcome of a ventricular tachycardia retrograde to the auricle.²

A case is now described of the type under discussion because it is hoped that it may throw light upon these questions, and in justification of the position adopted, that a rapid pulse which is *regular* is never present when the auricle is fibrillating, even though the ventricular form of venous pulse is found.

I am indebted to Dr. J. Rose Bradford for the opportunity of studying this patient.

The clinical history presents few features which have not been frequently duplicated by previously recorded cases of paroxysmal tachycardia; therefore it is essential to report only the more salient symptoms and signs which were noted.

J. W. was admitted to University College Hospital on April 1st, 1910. A Hebrew of 28 years, and by trade a cook, he was carried to hospital in a critical state, and subsequently gave the following history. Rheumatic fever and chorea, it was stated, had never occurred either in himself or in his family; apart from an attack of typhoid fever several years before admission, he had been healthy. Whilst mounting a flight of stairs he was seized with acute pain in the chest and distress of breathing. The pain was felt over the left half of the chest, the left abdomen, and eventually over the left arm and the left leg. He had never experienced a similar attack and its onset was not foreshadowed.

His condition when first examined gave rise to anxiety. The distress was evident and the collapse considerable. He complained of acute suffering, great pain in the precordial region, shooting into the neck and left arm; a feeling of compression in the lower regions of the chest; and a powerful throbbing in the neck. The skin was pale, cold and moist. He half reclined in bed; restlessness was prominent and he moaned incessantly; salivation was copious and he experienced nausea. The

respirations were rapid and the pulse was counted at between 200 to 210 beats to the minute. Cyanosis was not present. The heart sounds were tic-tac; no murmurs were audible; the dulness was increased to right and left; the impulse was diffuse in the fifth and sixth spaces in the nipple line. The chest was extremely sensitive to slight pressure and friction.

The attack of tachycardia which was present at his admission continued with its accompanying symptoms for eight hours, during which time the liver tended to enlarge, the heart dilated further, and venous engorgement became more evident. The attack ended abruptly and with immediate relief.

The subsequent history of the patient, during his long stay in the hospital, evolves itself into a series of attacks and the intervening intervals of rest. The paroxysms were frequent during the first two months of his stay and their duration varied from a few minutes to 48 hours. His freedom at a later date was attributable to rest, for the crises recurred when he first left bed. A number of the paroxysms originated in straining at stool. The onset was invariably sudden and the offset was always as abrupt. On several occasions the paroxysm ceased within a quarter of an hour of the injection of five drops of Cloetta's digalen or $\frac{1}{160}$ grain of strophanthine; on other and more numerous occasions the drugs were entirely without effect. Many means were resorted to, including ice packs and vagal pressure, but it was impossible to assert that a remedy had been found.

The condition between the paroxysms.

The patient was an extremely neurotic subject, poorly built and indifferently nourished; he presented no physical signs other than those discoverable in the heart. The lungs and abdomen were normal; there was never a sign of dropsy. The heart was enlarged. The right limit lay three-quarters of an inch and the left $4\frac{1}{2}$ inches from the middle line. The first sound was accentuated, the second normal. A distant presystolic murmur was present on many occasions, but varied in distinctness. A thrill was felt at the apex on one occasion only. The mechanism of the heart-beat as portrayed by polygraphic curves is shown in Fig. 1.

The pulse was regular as a rule, though at times when the usual rate of 70 to 80 was reduced to 50, sinus irregularity was noticed. The *a-c* interval was the full 0.2 sec..

The electrocardiograms are shown in Fig. 9, *I*, *II*, *III*. The lead from right arm and left leg (Fig. 9, *I*) is characteristic of mitral stenosis. P is of excessive height and bifurcates. The P-R interval is somewhat increased, measuring 0.18 to 0.20 sec.. In the lead from left arm and left leg (Fig. 9, *II*) R shows a notch on the upstroke. In the lead from right arm and left arm (Fig. 9, *III*) it shows a notch on the downstroke. The

conformation of these curves will be more specially referred to in the sequel. Occasional irregularities were felt at rare intervals, but none were recorded.

The condition during the attacks.

The symptomatology of the patient and many of the physical signs present during the paroxysms have been given. It remains to describe the mechanical and photographic records.

The polygraphic curves.—An example of polygraphic curves is shown in Fig. 2. The venous curve is of the ventricular form, the upstroke of

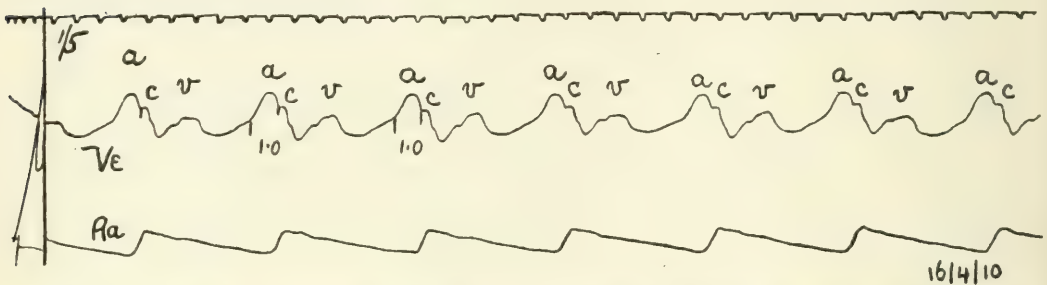


Fig. 1. Polygraphic curves taken during a period intervening between paroxysms, and showing the normal sequence of heart contraction, as indicated by the *a*, *c* and *v* waves in the jugular pulse. The *a*-*c* interval is 0.2 sec.. The time marker in this and succeeding curves is in 0.2 sec..

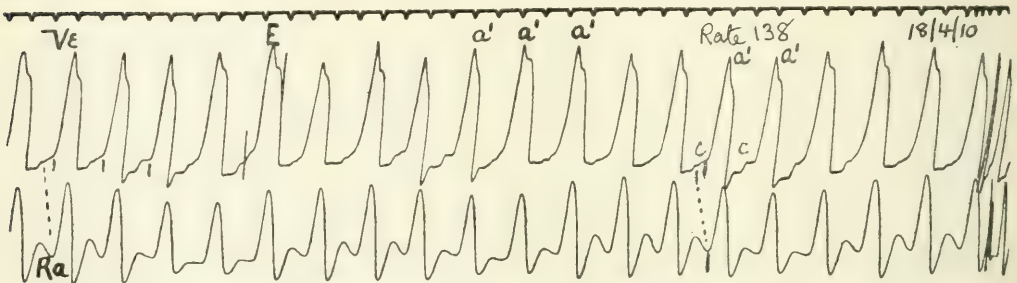


Fig. 2. Polygraphic curves taken during a paroxysm; the rate is 140; the venous pulse is of ventricular form, the large waves marked *a'* fall entirely within the limits of ventricular systole (*E*). The upstroke of *a'* occurs a little later than the point representing the onset of carotid pulsation.

the high peak coincides with the onset of the radial pulsation, or in other curves falls slightly before it; that is to say, the carotid upstroke falls slightly before or with the upstroke in the venous tracing. The complete wave has a duration of 0.2 sec., a little less than the duration of ventricular

systole as measured in the electrocardiographic curves. The beginning of the downstroke falls approximately at a point calculated as representing the bottom of the dip of the dicrotic in the carotid. The radial pulse is quite regular and markedly dicrotic.

The electrocardiograms.—A number of these curves were taken at different times and with different leads. They are shown in Fig. 9, *IV-VIII*. They are characterised by their regularity from beat to beat. There is no sign of irregular oscillation. Each peak and depression is duplicated from cycle to cycle.

Fig. 9, *IV* shows the curve obtained by leading from right arm and left leg. It consists of a tall peak R of similar duration to that of the similar lead during the slow periods (Fig. 9, *I*). It is succeeded by a deep depression, a further and gradual elevation and a last gradual depression. Then the next beat begins. The lead from left arm and left leg is shown in Fig. 9, *V*. It consists of a peak R, notched on the upstroke (marked ○). It is followed by a depression marked T. In no portion of the two preceding photographs is the curve flat; at no point can it be spoken of as isoelectric. The lead from right arm and left arm (Fig. 9, *VI*) presents a peak R with a notch upon the downstroke. It is succeeded by an upright after-swing T. The separate leads were adopted on each and all of the dates which the curves bear, but with the exception of the lead from right arm and left leg, an individual lead showed no conspicuous alteration. Two photographs of the lead from right arm and left leg are given because they are examples of paroxysmal curves at slightly different rates, namely 132 and 168. They differ in that with the faster rate the diastolic portion of the curve is curtailed and in that the latter is straighter with the accelerated heart-beat (Fig. 9, *VII*). A last lead is shown in Fig. 9, *VIII*, and it was taken from the junction of the sternum with the second costal cartilage and from the apex beat.

The interpretation of the curves obtained during the paroxysms.

Before proceeding to a description of the remainder of the tracings obtained from this patient, it will be profitable to discuss the significance of the paroxysmal curves themselves.

The venous curves are of the ventricular form, but two peculiarities call for remark. The excursion is of unusual amplitude and considered alone, the paroxysmal phebograms awaken a suspicion that the forcible venous pulsation, a pulsation readily appreciated with the finger, is not of ventricular origin, for curves of this amplitude and steepness and resulting from ventricular contraction are rarely if ever encountered except where there is great enlargement of the right heart and cavernous distension of the venous tributaries. The question as to whether auricle and ventricle

are contracting simultaneously suggests itself, for when a mechanism of this character is present similar venous tracings are met with.

The second peculiarity is one of less consequence. The upstroke in the venous curve does not coincide with the carotid but with the radial upstroke. This is of lesser significance, for the same time conditions are occasionally encountered, when it can be shown that the auricle is fibrillating.

The electrocardiograms.—Both the radial and electrocardiographic curves clearly show that the mechanism of the heart is regular during the paroxysms; and it may be held, I think with justification, that where a ventricular rhythm is regular the impulses which give rise to it are generated in a single focus. But at the present time I would not use this proposition as an evidence of the nature of the mechanism, for it is more desirable that the case should be utilised in confirmation of the view that, where the pulse is regular and rapid, the auricle is not fibrillating. That such is actually the case is at once evident, for in none of the leads is there any trace of the fibrillatory oscillation. The absence of fibrillation and the similar mechanism from one cycle to the next is shown by the absolute repetition of the individual electric curves; each beat is productive of a similar picture. The rhythm is consequently the result of impulse formation at a single focus, and it remains to locate the seat of this stimulus production. Taking the heart musculature as a whole, a large part of it may be eliminated at once by studying the electrocardiograms. The impulse formation is of supra-ventricular origin. The last conclusion is arrived at from the general conformation of the several curves in the slow and rapid rhythms and their comparison, and especially as a result of an examination of the curves given by separate leads. In the leads from right arm and left leg (Fig. 9, *I* and *IV*) the ventricular complexes differ during slow and fast rhythms respectively in that an inversion of T is present during the latter. A similar change has been reported in experimental auricular tachycardia, and the change is apparently associated with demonstrable conductivity changes in the heart.³ The slight prolongation of P-R interval (Fig. 9, *I*) is in accord with these observations, and, as will be seen, depressed conductivity was present in other curves from the same patient. (Fig. 10, 11 and 12.) A similar inversion of T is observed in the leads from left arm and left leg (Fig. 9, *V*), but in this figure also the remainder of the curve is a remarkable duplicate of that of Fig. 9, *II*; the notch on the upstroke of R (marked ○) is repeated. The resemblance in leads from right arm and left arm is striking (Fig. 9, *III* and *VI*). R and T are of the same type in both slow and paroxysmal curves, and a notch (marked ✱) is present upon both. The general conformation of the curve in Fig. 9, *VI*, is in itself evidence of the supra-ventricular origin of the beat, which gives rise to such a curve; and the special base apex lead from the chest wall (Fig. 9, *VIII*) provides additional support for the view. There is consequently no hesitation in pronouncing

the rhythm of the paroxysm as arising in a part of the musculature which lies above the division of the A-V bundle, and attention may be henceforth confined to the bundle itself and to the auricular tissue. Before pursuing the subject of localisation, the remainder of the curves will be described.

The curves obtained at the termination of the long paroxysms.

The four *polygraphic curves* (Fig. 3-6) were taken at one sitting and within a few minutes of each other; the end of a paroxysm of several hours' duration is shown in Fig. 3. It is succeeded by three brief runs of the quick beats, with a return to the normal sequence in each instance. A similar mechanism is shown in Fig. 4, which is a continuation of the last curve. At the end of the tracing a paroxysm, approximately 10 minutes in length, has its onset. At its termination the two remaining curves were secured. Fig. 5 and 6 are examples of the slow normal rhythm, interrupted by premature beats.

In the investigation of all cases of paroxysmal tachycardia the end curves are of the utmost value and throw considerable light upon the nature of the disorder with which the heart is affected. As in previously reported cases, so in this patient, the paroxysms end in post-paroxysmal pauses, the duration of which is an indication of the ectopic character of the new rhythm. The normal stimulus production has been disturbed by the interference of pathological impulse formation at a point distant from the pacemaker. The end pauses of the long paroxysm shown in Fig. 3, and of the short paroxysms succeeding it, are of duration $\frac{3}{5}^{\cdot 7}$ to $\frac{5}{5}^{\cdot 8}$ sec. in the radial curve (the auricular pauses are $\frac{3}{5}^{\cdot 4}$, $\frac{3}{5}^{\cdot 9}$, $\frac{4}{5}^{\cdot 0}$, $\frac{4}{5}^{\cdot 0}$ sec.). The majority of the ventricular pauses following single premature beats (Fig. 5 and 6) are of duration $\frac{3}{5}^{\cdot 5}$ to $\frac{5}{5}^{\cdot 9}$ sec. (the corresponding auricular pauses $\frac{3}{5}^{\cdot 9}$, $\frac{4}{5}^{\cdot 0}$, $\frac{3}{5}^{\cdot 6}$, $\frac{4}{5}^{\cdot 4}$ sec.). The mechanism though lacking absolute regularity is similar in one case and the other. Following the paroxysms and following the single premature beats, the length of the pause in the auricular curves is greater than the distance between adjacent beats of the normal rhythm in Fig. 5 and 6 (the latter varies from $\frac{3}{5}^{\cdot 0}$ to $\frac{3}{5}^{\cdot 5}$ sec.).

The venous curve shown in Fig. 3 is of particular value, for it allows a comparison of the amplitude of the paroxysmal curves and the *a* and *c* waves accompanying beats in which the contraction is sequential. The second ventricular beat which follows the post-paroxysmal pause probably belongs to the normal rhythm; it is followed by four premature beats, each accompanied by a tall venous wave marked *a'*. Now it is evident that these waves are not of purely ventricular origin for the remaining *c* waves of the curve are extremely insignificant. It is rational to assign to them a new factor of production, and the increased amplitude can be explained by supposing that a premature auricular contraction has occurred.

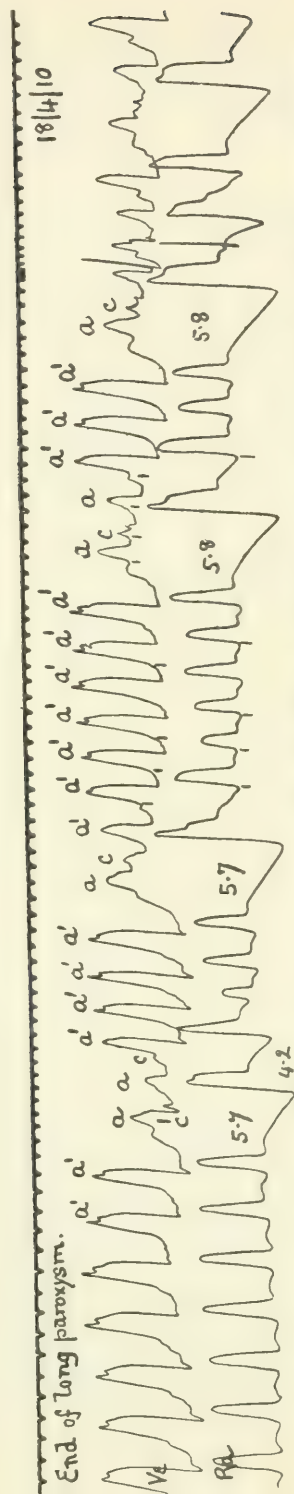


Fig. 3. Polygraphic curves showing the termination of a long paroxysm of the same nature as that shown in Fig. 2. The end of the paroxysm is marked by a pause at the return to the normal sequence, and is followed by the occurrence of three short paroxysms of a similar character.

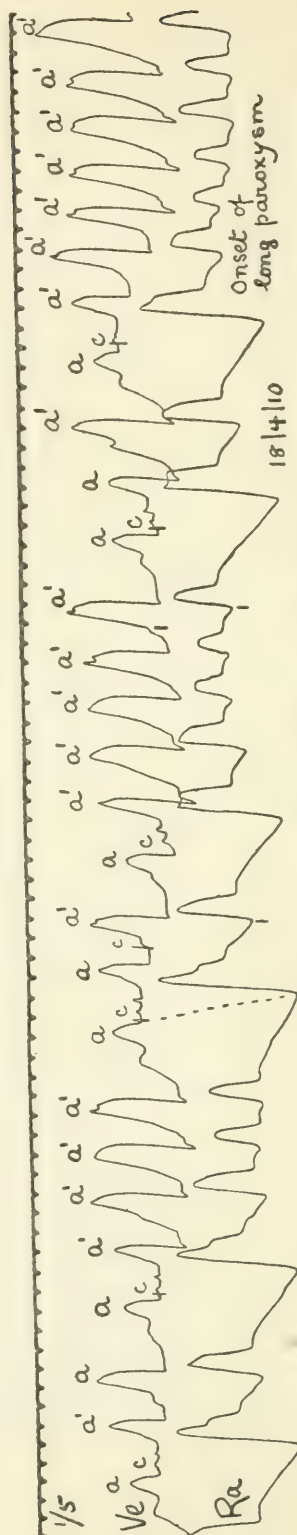


Fig. 4 is a continuation of the preceding figure, and shows the irregularity which follows the end of a paroxysm, as a result of interruption of the normal sequence by beats of similar form to those of the paroxysms themselves. At the end of the curve a fresh and prolonged paroxysm commences.

And this explanation is fully justified by a detailed examination of the curve. The height of the new wave exceeds that of the normal *a* waves, but each is accompanied by a ventricular systole. The new waves vary also in their relationships to the radial beats, in itself a conclusive argument against their ventricular origin; further, the closer the coincidence with the ventricular contraction the higher is the resultant wave. The conclusion that the new waves are of auricular origin is beyond question.

The interpretation of this curve and the continuation of it (Fig. 4) is fully borne out by the succeeding tracings, in which single interruptions of the slow rhythm are seen. Examine Fig. 5 and 6. It may be said that high waves also occur as accompaniments of beats following long pauses. But there is good reason for this variation: it is due in these instances, as in those previously discussed, to synchronous auricular and ventricular contraction; in the last instances the ventricle escapes and beats are present which belong to an ideo-ventricular rhythm. Where a comparison with electric curves provides an easy solution of the mechanism (Fig. 10, 11 and 12), positive evidence of simultaneous contraction is forthcoming.

The electric curves (Fig. 10, 11 and 12) are examples of a large number of photographs, and are selected to illustrate special points connected with the interpretation of the mechanism as presented by Fig. 5 and 6. The venous and electric curves referred to were taken within half an hour of each other. In the radial curves of Fig. 5 and 6 the beats occur in groups of two and three. Similar groups are shown in the electric curves. In Fig. 10 two complete groups of three ventricular cycles are shown. Each heart cycle is accompanied by P, R and T variations. In each group the P-R interval increases from 0.6—1.7 sec., and the last beat, which is of anomalous form, is succeeded by a long pause. The relation of the P and R variations is similar to that of the *a* and *c* waves in Fig. 6. The shortening of the P-R interval after a pause, to $\frac{1}{3}$ sec., is conspicuous. In other curves it is still greater, and the interval diminishes until P and R partially coincide (Fig. 11), or until the auricular complex is completely buried in the ventricular complex (Fig. 12). As all stages of shortening are present, it is impossible in certain given instances to ascertain whether the ventricular beat is a response to the auricular, or whether it is generated in the ventricle. It is probably ideo-ventricular in Fig. 11. It is certainly ideo-ventricular in Fig. 12; the last beat in the curve consists of a superimposition of auricular and ventricular complexes. Thus the coincidence of *As* and *Vs*, suspected after an examination of the venous curves, is demonstrable.

The paroxysmal cycles are known, from the consideration of venous and electric tracings, to consist of simultaneous auricular and ventricular systoles; but this is not obvious in the electric curves alone (Fig. 9). Neither can the auricular contractions, which are recognised as falling with the

last beats of the groups (Fig. 5 and 6 and Fig. 10, 11 and 12), be identified in the electric curves. The reason of the failure of the premature P variations (single or paroxysmal) in the electric curves is clear. The auricular contractions take an abnormal course in the auricle; that is to say, they commence at a point in the musculature other than the pacemaker. Under these circumstances the electric changes which accompany such contractions are anomalous, and in the present instance the form of the curve to which they give rise is unknown. That auricular contractions originating in an abnormal fashion give rise to abnormal electric variations is known from a study of the experimental facts in regard to them.³ In this case the abnormal Ps are probably of a type approaching the isoelectric position. It was hoped that a clearer appreciation of the form of anomalous Ps would be obtained by comparing the cycles in various leads, and with slightly divergent heart rates (Fig. 9, *IV* and *VII*), but the analysis has been found impracticable. We remain satisfied that the contractions of auricle and ventricle are simultaneous, although the identification of the former is impossible in the electric curves.*

Returning to the mechanism of the paroxysms, and knowing that each cycle consists of a synchronous As and Vs, there are two alternative interpretations of the events open to us. It may be supposed that the auricle and ventricle contract together in response to a single stimulus originating between them, or that each ventricular contraction is a response to the auricular systole which coincides with the preceding ventricular contraction. Either interpretation meets the facts of the case in so far as we have yet considered them. The instants at which As and Vs fall in the venous curves are fully determinable, and we have to consider the functional relationships of the separate beats.

For purposes of illustration I have diagrammatised the two interpretations of the first short paroxysms of Fig. 3 (in Fig. 7, *1* and *2*) and the first six ventricular cycles of Fig. 6 (in Fig. 7, *3* and *4*).

(1) Dealing with the first interpretation, namely simultaneous As and Vs, as a result of As falling back upon Vs (Fig. 7, *1* and *3*), it will be obvious that if this explanation is adopted, it necessitates the assumption that all single premature auricular contractions are blocked. But it likewise involves the unreasonable assumption that the last beat of each paroxysm, be it short or long, is blocked too.

(2) Adopting the second interpretation (Fig. 7, *2* and *4*), namely simultaneous contraction of A and V as a result of a single impulse formed between them, we have to allow that the auricular contraction of the normal sequence directly preceding the onset of the paroxysm is blocked, or if this is not blocked, then the first impulse starting the paroxysmal contraction gives a response in the auricle alone.

* An instance in which venous curves show what electric curves will not demonstrate.

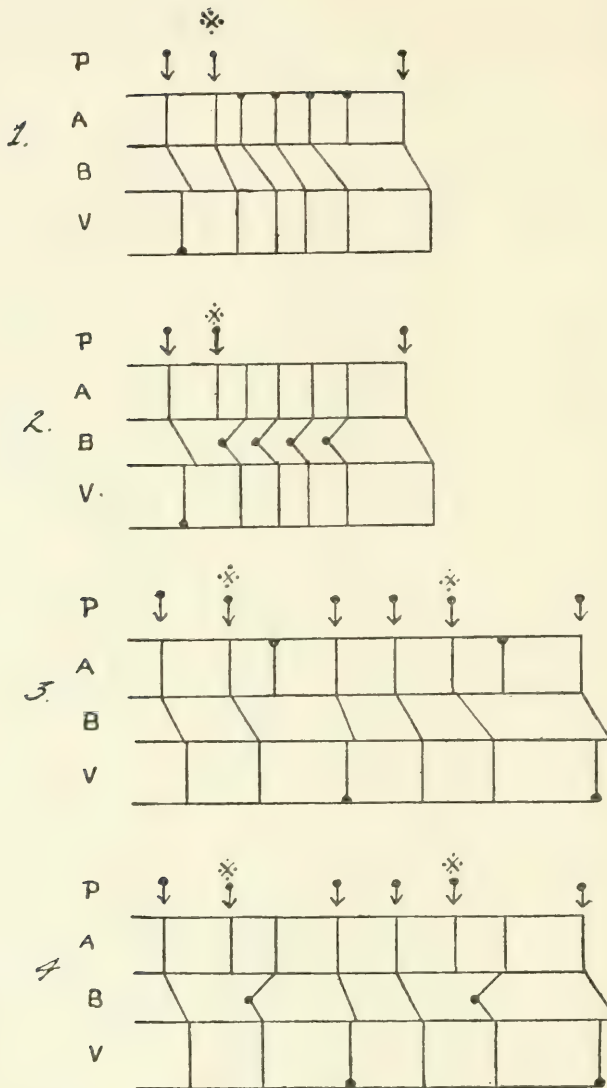


Fig. 7. Four diagrams illustrating the possible interpretations of mechanism in two portions of the preceding curves. Fig. 7, 1 and 2 are alternative explanations of the first short paroxysm of Fig. 3. Fig. 7, 3 and 4 are alternative and parallel explanations of the first five beats of Fig. 6. The arrows drawn above each diagram represent impulses which descend from the pacemaker and give rise to auricular contractions. A represents the auricle, B represents the junctional tissues, and V represents ventricle. The black dots are intended to represent the point at which the impulses may be supposed to arise.

The facts will not permit a positive decision in one way or the other, but on the whole they are in favour of the second explanation. No appreciable change has been found in the relationship of As to Vs during the paroxysms with considerable divergence of rate, and no ventricular beat has ever been dropped at such times. Finally, we can only conclude that we are dealing with a supraventricular form of paroxysmal tachycardia, in which the contraction of auricle and ventricle is simultaneous, and that of two propositions (delay in conduction from A to V, and impulse formation between A and V), which might be adopted in explanation of the phenomena, the second appears to be the more reasonable.

Certain features of the curves remain for brief discussion or mention.

(1) The last ventricular complex of each separate group in Fig. 10, 11 and 12 is of anomalous form. T is partially inverted. Such beats are of a form transitional between the normal complexes on the one hand and the paroxysmal complexes on the other. The alterations in a ventricular complex resulting from a premature auricular contraction have been described in detail in an article to the last number of this *Journal*,³ but evidence was produced which showed that the prematurity of the auricular contraction is not the sole cause of the alteration in the ventricular curve. It appears to associate itself with two phenomena; the first of which is the close proximity of the premature beat and that which precedes it (brought about in the present instance by variation in the lengths of the As-Vs intervals), and the second of which is the presence of demonstrable changes of conductivity in some portion of the heart muscle. Fig. 12, taken at a fast rate, is given that the comparison between the single anomalous complex and the beats of the paroxysmal type may be more readily compared. There is no reason to suppose from the general conformity of the single anomalous beats that they have arisen other than in response to the preceding auricular contraction.

(2) The single atypical beats of Fig. 10, 11 and 12 are of interest in showing a gradual decline of T. It is some while before the curve becomes horizontal or isoelectric. The usual experience in dealing with premature complexes is to find the total length of an individual ventricular complex equal, within small errors of measurement, to the complex of the normal rhythm.⁴ In this instance there is a marked divergence from the customary findings, but the cause of the extension of T is quite obscure. It cannot be assigned to activity of the auricle; the prolongation is too great. A similar condition is found in the paroxysms themselves. In the leads from right arm and left leg (Fig. 9, *IV* and *VII*), no portion of the curve is isoelectric for any length of time. Here, again, the meaning of the phenomenon is not ascertainable.

The ventricular form of venous pulse in association with retrograde heart-beats.

In the introductory paragraphs of the present communication it was stated that the ventricular form of venous pulse is to be anticipated when a paroxysm of tachycardia, originating in the ventricle, dominates the rhythm of the whole heart. I have met with two clinical instances in which ventricular paroxysms were present, but they were of brief duration and the venous curves were not obtained.

A polygraphic curve taken from an anæsthetised dog, and showing a complete paroxysm of ventricular tachycardia is shown in Fig. 8. The paroxysm was induced by interrupted stimulation of the ventricle; the chest wall was closed at the time. The normal sequence of events is shown in the opening cycles of the curve. The first interruption consists of a single premature ventricular beat, which fails to affect the femoral curve. One cycle of normal sequence follows, and a ventricular paroxysm of 15 beats succeeds it. The first four auricular peaks, which occur after the onset of the paroxysm, are placed at regular intervals, and at the expected points in continuation of the preceding auricular rhythm. They vary in height according to the stage of ventricular systole at which they fall, being taller when coinciding with the earlier phases of ventricular contraction. The venous curve then assumes a perfectly regular appearance. The auricle and ventricle are now contracting together and at constant time relationships to each other. In other words, the ventricular rhythm has become regularly retrograde. The representative of auricular contraction is seen rising from the plateau in each cycle of the venous curve. That this peak is in reality the result of auricular contraction is known by comparing the two cycles marked x, x. In the venous curve they show a close resemblance to each other, differing only in the very slightly earlier appearance of *a* in the first of the two cycles considered. Its appearance in the first cycle marked x is not due to retrogression, but it is due to the expected response of the auricle to sinus impulse formation. On the other hand, it appears prematurely in the second cycle, and represents the first retrograde auricular contraction. The venous curve during the reversed mechanism, which is maintained from this point onwards, is of the ventricular form.

SUMMARY.

A case of paroxysmal tachycardia is described in which the ventricular form of venous pulse was present, as a result of simultaneous contraction of auricle and ventricle.

The ventricular form of venous pulse is also found (experimentally) when reversed heart rhythm is present.

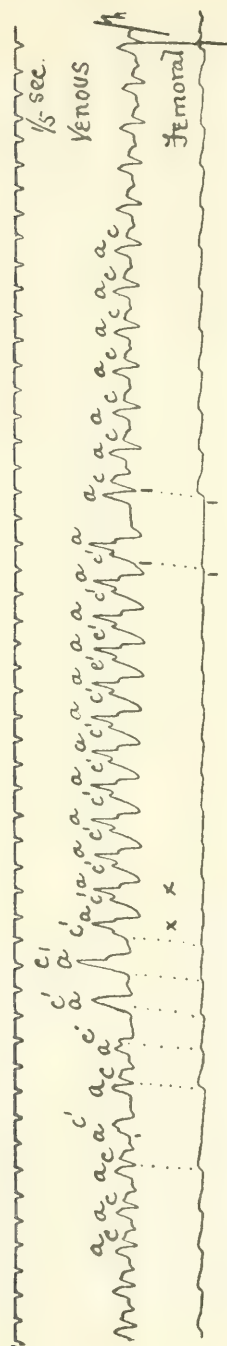
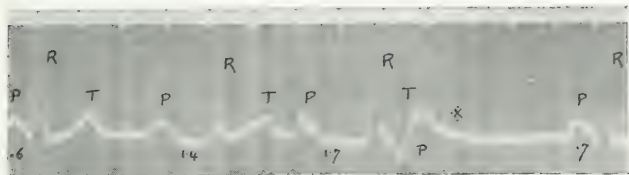


Fig. 8. A polygraphic curve from a dog, showing the form of the venous pulse when the rhythm of the heart is reversed and auricle is responding to ventricle.

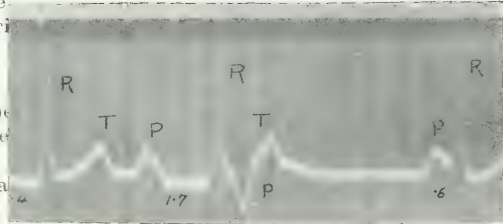
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- ⁷ WENCHEBACH. Archiv. f. Anat. u. Physiol., 1908, Phys. Abth., 53.



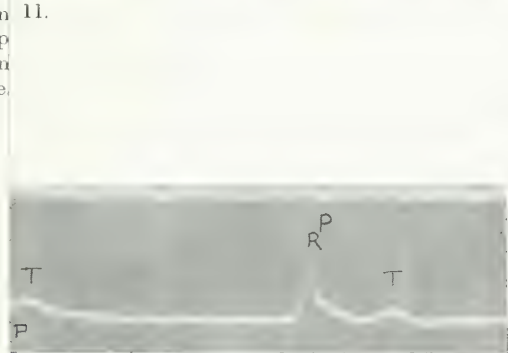
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Fig. 1



Fig. 2



Fig. 3

THE SITE OF ORIGIN OF THE MAMMALIAN HEART-BEAT; THE PACEMAKER IN THE DOG.

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AND

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WHILE the location of the pacemaker of the heart in the cold-blooded vertebrates has been accomplished, and while it is known that it lies in a chamber, which is separated from the auricle in these animals, namely, the sinus venosus, the problem of its isolation in the mammalian heart has been surrounded by great difficulties, and it cannot be said that the numerous investigations have even approached a clear conclusion until the last few years. It has been investigated from many points of view, most of them suggested by corresponding experiments and observations undertaken on the amphibian and the reptilian heart. We do not intend to discuss the majority of these observations in any detail, for after a careful consideration of the facts, we cannot see that any decisive conclusion can be arrived at from most of them. More especially we refer to the observations on the dying heart and on the perfused heart, knowing as we do the delicacy of the mechanism investigated, and believing that a dislocation of the pacemaker occurs with slight provocation. In the dying and perfused heart it is obvious that the condition of the musculature is one of great abnormality.

The lengths of pauses following a contraction excited artificially from various regions of the auricular tissue seem to lead us no further; the results lack uniformity and definiteness.

Excision or destruction of an area of caval or auricular tissue or the isolation of a portion of the same tissue have been attempted on many occasions. As in the instance of observations upon the local warming

* Working under the tenure of a Beit Memorial Research Fellowship.

and cooling of the mouths of the great veins, the majority of such experiments have been performed upon perfused hearts; and in the instances where the heart was observed *in situ* and under more natural conditions, as in the case of Erlanger and Blackman's investigations,¹ the experiments fail in their main objective, *i.e.*, the location of the first active point. They do little more than suggest, what has already been suspected, that the destruction or isolation of the normally and primarily active point leads to little or no change in the rate of the rhythm. From this point of view we may refer to some recent investigations made by Jaeger.³ This writer reports the destruction by cautery of a large area of tissue in the neighbourhood of the sulcus terminalis and superior vena cava, a destruction including the whole of the specialised tissue lying in this neighbourhood and known as the sino-auricular node. Such experiments do not detract from the importance of the sino-auricular node, for if the original pacemaker is destroyed, it is probable that another portion of the auricle assumes this function without an appreciable change in rate or rhythm.

We question whether the conditions can be satisfied in the absence of electric observations. We have, it is true, very suggestive evidence on the morphological side, since the discovery by Keith and Flack of a collection of specialised tissue at the superior caval end of the sulcus terminalis.

The experiments which are described in this communication are especially directed towards an investigation of the area in the neighbourhood of this node in which fine muscle fibres and a network of nerves and ganglia are intermingled. Our experiments were confined to the right auricle, for it had been previously shown by another method⁵ that the pacemaker of the heart lay in the right auricle, and our attention was specially directed to that portion of the right auricle which includes the portion of the sulcus terminalis abutting upon the superior vena cava. A full description of the method referred to will be found in a preceding number of this *Journal*; the method depends on a comparison of the electric complexes yielded by the auricle when beating normally and when responding to excitations thrown in at various points on its surfaces. It has been found that the normal auricular complex is duplicated when the point of excitation lies in the neighbourhood of Keith and Flack's node, and when it lies in this region only. The method is not sufficiently delicate to permit an absolute location of the pacemaker. It consequently occurred to us to adopt direct leads from the superficies of the auricle, and to search for the point of primary negativity, for primary negativity is generally recognised as representing primary activity.

It had already been shown in two preliminary experiments⁶ that the superior vena cava becomes negative before the inferior cava. Recently Wybauw has published a preliminary report of similar observations which require more detailed attention. His actual results will be considered in the discussion which terminates this paper.

Method.

For the purpose of our experiments we have used medium-sized dogs, anæsthetised with morphine, paraldehyde and ether. The chest was opened under artificial respiration. The dog was laid upon its left side and the right auricle was exposed by the removal of one, two or three ribs. With the wound retracted, the pericardium was opened in the line of the sulcus terminalis; the cut edges were stitched to the chest wall and the heart slung with the least possible disturbance of its natural position. Particular care was taken to avoid kinking of the cavæ.

The electrodes used were non-polarisable and were of the form described by Gotch,² consisting of small rubber tubes pulled over the end of glass tubes half filled with kaolin. A few strands of worsted, daubed with kaolin, extended from the kaolin in the glass tube to the end of the rubber tube, and projecting slightly beyond the latter served as the actual point of contact. In the glass tube above the mass of kaolin was a saturated solution of sulphate of zinc in which lay the zinc rods, connected directly with the galvanometer. The contact surface of the electrodes was 1.5 to 2.0 mm., but we fix the point of contact within an area approximately 5.0 mm. in diameter, to allow for slight possible shifting or alteration in site of the electrode during the course of the experiment.

After certain preliminary experiments which will be mentioned subsequently, we found it convenient to adopt a certain routine plan of leads from the start to the finish of experiments. Our object was to fix the point of primary negativity upon the exposed surface of the right auricle.

The observations were commenced by leading from the cavo-appendicular angle (T^2) to the mid-point of junction of inferior vena cava and auricle (T^7 in the nomenclature we adopted). (The leads may be seen in Fig. 1 to 7.) From this point on, the same electrode was maintained in contact with T^2 , providing that T^2 was found to be primarily negative. If T^2 was found to be primarily negative to T^7 the electrode at T^7 was moved to a point approximately midway between the leads, namely T^5 ; T^2 continuing to be primarily negative, was retained, while the distance was again decreased, placing the lower electrodes at T^1 or T^3 . Subsequently other points in this line were tested as against T^2 ; for example, T^6 . In this manner we arrived at that point on the sulcus which was primarily negative to all other points in the same line; we then proceeded to complete a circle of contacts around this point (T^2), and to test such contacts against the hitherto primarily negative point.

The circle was of necessity broken at one point, representing a continuation of the sulcus above T^2 ; but in several experiments we have used a contact on the surface of the auricle directed towards the aorta and beyond the summit formed by the angle of junction of appendix and superior vena cava (T^1). In a number of experiments we have tested other

points on the surface of the appendix, superior vena cava and the main mass of auricular tissue, and have also tested the right pulmonary vein, exposed by the operative procedure described.

The points of contact utilised have comprised : seven points placed in a line along the sulcus terminalis (spoken of as T¹ to T⁷ respectively), six points on the superior vena cava (spoken of as S¹ to S⁶ and numbered from above downwards towards the auricle), four points on the appendix and auricular surface (A¹ to A⁴), two points on the pulmonary veins (P¹ extrapericardial and P² intrapericardial). The approximate position of the points will be seen by reference to the diagrams accompanying the protocols (Fig. 1 to 7).

From time to time and in many of the experiments we have taken the contact leads from the upper and lower edges of the wound, and these leads have been adopted for a special purpose. It is known that the point of impulse formation in the auricle is subject to variation from time to time under abnormal conditions, and as a result of our experience in this and in the preceding series of observations, it has been apparent that the factors which induce this dislocation of the seat of impulse formation are in the nature of comparatively small interferences and often beyond control. An original lead from the cephalic and caudal edges of the wound, directly after exposure of the heart, gave us the outline of the normal auricular complex for the experiment and for this particular lead. Subsequent observations taken at intervals from the same points allowed us to ascertain the presence or absence of disturbance in the site of impulse formation during the course of the experiment. These control curves, giving in every instance an outline similar to the normal electrocardiogram as obtained by leads from the base and apex of the heart (and consisting of three main variations, P, R, and T respectively, in the base negative direction), served also as the standard of the direction of the variation obtained in the direct auricular leads. For the electrode placed upon the upper edge of the wound was that customarily used as the arm electrode in routine work, and was invariably placed upon the cavo-appendicular angle and maintained there in succeeding observations. Negativity of the base of the heart is represented in the control leads by a variation in the upward direction.

At the conclusion of an experiment the points of contact, employed during that experiment and marked upon a diagram of the heart prepared at the time, were fixed upon the auricular wall itself by means of fine sutures. A single suture was passed beneath each contact point, so that the latter lay midway between the points at which the suture perforated the auricle. The heart was excised, washed and fixed ; at a subsequent date the tissue lying along the sulcus was excised, cut into strips and imbedded. The subsequent identification of the original contact points was facilitated and rendered more certain by arranging the cuts transversely to the sulcus and midway between the points marked. Blocks of tissue were thus obtained and labelled T², T³, T⁴, etc., respectively. The

upper and lower ends of each block were known. Thus each block contained the whole of the corresponding contact point and a small margin of tissue around it.* Sections were cut of all the blocks, starting at T², and they were continued until a point was reached several millimetres below the last trace of the node; in some cases they extended to the inferior vena cava. Usually every twentieth section was mounted and stained in series; in the first heart examined every section was mounted. From each block and for purposes of measurement a few sections were selected at those intervals at which divergence in the amount of the nodal substance was apparent.

The outline of the node was projected by camera lucida and drawn on squared paper. The image was enlarged to such a size that each square represented a convenient fraction of a square millimetre. The width, depth and area of the cross-section of the node were readily measured, and these measurements are included in the table accompanying each separate protocol. The outlines of the node are obscure in many places, and in other places outlying masses are not infrequently found. It has been the rule to neglect all portions of the tissue not clearly differentiated and to include outlying masses in the calculation of the area. The small strands of tissue directly surrounding the nodal artery and its branches have been neglected. In this way we have obtained an estimate of the size of the node, its situation and the relationship to the points of contact of the electrodes in the corresponding experiments.

Observations.

The protocols of seven experiments are given in the succeeding pages, but before proceeding to a detailed account and discussion of the observations, we have to refer to certain experiments which are not contained in the protocols. At an early stage of the investigations, we made complete electric observations on three animals. In the first of these instances the heart was allowed to distend *in situ* and remained distended so long that the specimen was of no use for histological examination. In this and two further experiments we obtained electrical variations with the several leads, of a very complex nature, and which appeared to us to be inconsistent with the origin of the heart-beat at a single point during a given experiment. In the last two experiments referred to, in both of which numerous leads were instituted, we seemed to obtain evidence, from the direct leads, of a displacement of the primarily negative point during the progress of the observations. We were confirmed in this view in the two later experiments referred to, in that the auricular complexes of the controls from the upper and lower edges of the wound failed to remain

* The margins between contact points is exaggerated in Fig. 1-7.

constant in form. In the first experiment no such controls were taken. In two of the experiments leads which were taken from the same points gave divergent and contradictory results at different stages of the observations. Thus while we obtained evidence of the dislocation of the primarily negative point, we could not say that we could clearly establish one point as primarily negative at an early stage and another as primarily negative at a later stage of the experiment. We believe that the difficulty may have arisen from a repeated change in the mechanism of the auricular beat. In brief, it was impossible to ascertain any single individual point on the superficies of the auricle as constantly and primarily negative. For this reason we have rejected the results obtained in these experiments.

Protocols.

DOG B Q.

Morphine, paraldehyde, ether. Tracheotomy, artificial respiration. The right auricle was exposed by removal of portions of the right third, fourth and fifth ribs. The dog was laid on its left side; the wound retracted, and the pericardium opened in a line parallel with the sulcus terminalis; the edges of the pericardium were stitched to the chest wall. The heart continued to lie in its pericardial sack throughout the experiment. The leads were taken directly from the surface of the heart with non-polarisable electrodes.

Leads taken from the upper and lower edges of the wound showed P, R, and T directed upwards (*i.e.*, in the base-negative direction).

Subsequent leads are tabulated below the accompanying diagram.

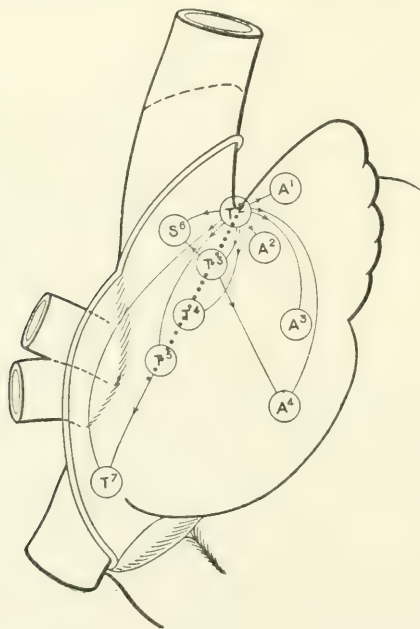


FIG. 1.

Fig. 1. A diagrammatic representation of the right auricle as seen in the operation described in the text. The reflected pericardium is seen to the left as a double outline crossing the superior vena cava obliquely, the right pulmonary veins and the inferior vena cava. A dotted line on the superior vena cava indicates the end of the musculature. The circles indicate the centres of the points of contact used for leads. Those which lie in the line of the sulcus terminalis are marked T² to T⁷ respectively. The general direction of the contraction wave, as indicated by the current flow, is represented by an arrow joining two circles. The position of the node, ascertained histologically, is shown by a broken line of heavy dots, starting at T² and passing towards the inferior vena cava to a point somewhat below T⁵. In this and succeeding figures the representation is approximate. The circles are drawn rather smaller than we are able to locate the points of contact with accuracy.

Lead.			Curve.			Direction of variation.
T ² -T ⁷*	..	..	Monophasic	..	..	Upward.
T ² -T ⁵	..	..	diphasic	..	..	upward, then downward.
T ⁵ -T ⁷	..	..	triphasic	..	..	upward, downward, then upward.
T ² -T ⁴	..	..	—	..	..	upward.
T ² -T ³	..	..	triphasic	..	..	upward, downward, then upward
T ² -A ³	..	..	diphasic	..	..	upward, then downward.
T ² -S ⁶	..	..	—	..	..	upward.
T ² -A ⁴	..	..	monophasic	..	..	upward.
T ² -A ³	..	..	diphasic	..	..	upward, then downward.
T ² -S ⁶	..	..	monophasic	..	..	upward.
T ³ -A ⁴	..	..	diphasic	..	..	upward, then downward.
T ³ -S ⁶	..	..	monophasic	..	..	upward.
T ² -A ²	..	..	diphasic	..	..	upward, then downward.
T ² -A ¹	..	..	diphasic	..	..	upward, then downward.
T ² -A ¹	..	..	diphasic	..	..	upward, then downward.

T² was consequently demonstrated to be primarily negative to all other points in the line of the sulcus terminalis and also to five other points. Four of the latter lay upon the right auricle and its appendix and the fifth lay upon the superior vena cava.

Of the outlying leads,† all those tested showed primary negativity of the point proximal to T².

The points of the leads were marked while the heart lay *in situ*. The heart was excised and preserved for histological examination.

Serial sections 10 μ thick, and transverse to the sulcus terminalis, were cut, and every twentieth section mounted and stained with hæmatoxylin followed by Van Gieson's picro-acid fuchsin. The sections were examined in series and a sufficient number selected for more exact measurement, at such intervals as to give the shape and dimensions of the node approximately. The node begins on the lateral surface of the right auricle 0.9 mm. caudal‡ to the cavo-appendicular angle and extends for 14 mm..

* The contact first mentioned was formed by the electrode originally placed on the upper end of the wound.

† By outlying lead we mean one in which the electrodes lie so that neither is in the immediate neighbourhood of the primarily negative point. (Such leads are usually arranged in the lines of radii drawn from the latter.)

‡ We use the terms "cephalic" and "caudal" to indicate the appendicular and inferior caval termination of the sulcus.

The actual measurements of the node are outlined in the accompanying table.

Table giving measurements of S-A node in the heart of Dog B Q.

Block, including area.	Distance in mm. from beginning of node.	Cross-section of node at selected intervals.			REMARKS.
		Width in mm.	Depth in mm.	Area in square mm.	
T ²	0.0	0.2 +	0.1 +	0.02	
	0.2	0.6 +	0.2 +	0.08 —	
	0.4	0.5 —	0.3 +	0.07 +	
	0.8	0.5 —	0.3 —	0.08 —	
	1.2	0.4 +	0.3 —	0.06 +	
T ³	2.0	0.6 +	0.4 +	0.14 —	
	2.6	0.8 —	0.4 —	0.17 +	
	2.8	1.3	0.4 —	0.30 —	
	3.4	1.4 +	0.5	0.38 +	
	3.6	1.9 +	0.4 —	0.43 —	
	4.2	1.8 —	0.7 —	0.50 —	
	4.6	1.6	0.6 +	0.47 —	
	4.8	1.9 +	0.6	0.53 —	
	5.2	1.5	0.5	0.42 +	
	5.6	1.6	0.5 —	0.42 —	
	6.0	2.1 —	0.5 —	0.44 —	
	6.4	1.1 +	0.4 +	0.31 —	
	6.6	1.4 —	0.4	0.35 —	
T ⁴	6.8	1.2 —	0.3 +	0.21	
	7.6	1.1 —	0.2 —	0.13 +	
	9.4	1.2 +	0.2 —	0.11 +	
T ⁵	10.6	2.5	0.3 —	0.26 —	
	12.2	1.6 —	0.3 +	0.16 +	
	13.6	2.0 —	0.12	0.10 —	

14.0 + mm. = total length of node.

In shape the node resembles a *spindle* cut in half lengthwise, with the flat surface toward the epicardium.

The length and position of the node are represented in the accompanying diagram by the dotted line.

The point of primary activity (negativity), T², corresponds to the upper (cephalic) end of the sino-auricular node, but does not include the bulbous portion. The bulbous portion of the node corresponds to the point T³, a point just caudal to T².

Nodal tissue having a different histological structure was found at T² and not at the most expanded point T³.

DOG B R. (Small dog; small heart.)

The anaesthesia and procedure were exactly as described in the previous experiment, except that portions of the third and fourth ribs alone required resection to render the sulcus terminalis and venæ cavæ readily accessible.

Leads taken from the upper and lower edges of the wound showed P, R, and T directed upwards (*i.e.*, in a base-negative direction).

Subsequent leads are tabulated below the accompanying diagram.

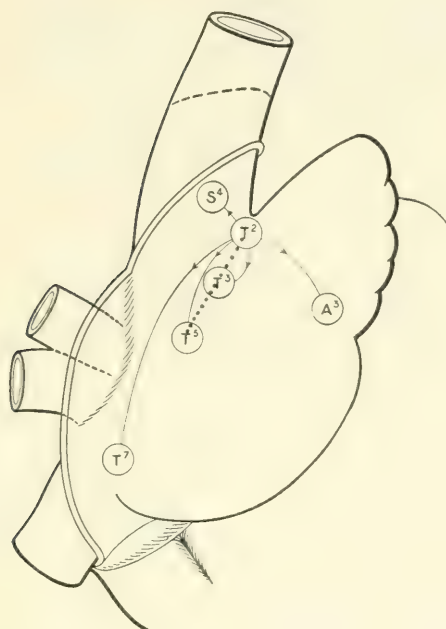


Fig. 2.

Lead.			Curve.			Direction of variation.
T ² -T ⁷	..	..	Monophasic	..	..	Upward.
T ² -T ⁵	..	..	diphasic	..	..	upward, then downward.
T ² -T ³	..	..	monophasic	..	..	upward.
T ² -S ⁴	..	..	diphasic	..	..	upward, then downward.
T ² -A ³	..	..	diphasic	..	..	upward, then downward.

T² was consequently demonstrated to be primarily negative to all other points in the line of the sulcus terminalis, and also to two outlying points, one on the superior vena cava and one on the auricle.

The points of the leads were marked while the heart lay *in situ*; the heart was excised and preserved for histological examination.

Serial sections 10 μ thick and transverse to the sulcus terminalis were cut, mounted and stained with hæmatoxylin, followed by Van Gieson's picro-acid fuchsin. The sections were examined in series and a sufficient number selected for more exact measurement at such intervals as to give the approximate shape and dimensions of the node.

The node begins on the lateral surface of the right auricle 1.6 mm. caudal to the cavo-appendicular angle and extends for 8.84 mm..

*Table giving measurements of S-A node in the heart of Dog B R.**

Block, including area.	Distance in mm. from beginning of node.	Cross-section of node at selected intervals.			REMARKS.
		Width in mm.	Depth in mm.	Area in square mm.	
T ²	0.00	—	—	0.01 +	
	0.37	0.56	0.32	0.19 +	
	0.75	0.80	0.24	0.17 —	
	0.92	—	—	0.34 +	
	1.10	1.44	0.56	0.81 +	
	1.13	1.84	0.56	0.82 —	
	2.59	1.36	0.56	0.55 +	
T ³	3.19	1.36	0.32	0.27 —	
	3.53	1.44	0.28	0.27 —	
	4.94	1.36	0.20	0.27 —	
	5.61	1.04	0.16	0.17 +	
	6.19	0.96	0.08	0.06 +	
T ⁵	6.49	1.44	0.08	0.08 +	
	7.59	—	—	0.06 —	
	7.86)	—	—	minute	Fifteen small bits of node.
	to				Four bits of node.
	8.84)				Three " " "
					Five " " "
					Two " " "

8.84 mm. = total length of the node.

The shape of the node resembles that of a *club*.

The point of primary activity (negativity), T², corresponds to the beginning and bulbous portion of the sino-auricular node.

DOG B V.

Anæsthesia and procedure as in previous experiment.

Leads from upper and lower edge of the wound showed P, R, and T directed upwards.

Subsequent leads are tabulated below the accompanying diagram.

<i>Lead.</i>		<i>Curve.</i>		<i>Direction of variation.</i>
T ² -T ⁷	..	Diphasic	..	Upward, then downward.
T ³ -T ⁷	..	diphasic	..	upward, then downward.
T ² -T ⁵	..	diphasic	..	upward, then downward.
T ² -T ⁵	..	diphasic	..	upward, then downward.
T ² -T ³	..	diphasic	..	upward, then downward.
T ² -T ³	..	diphasic	..	upward, then downward.
T ² -S ⁴	..	diphasic	..	upward, then downward.
T ² -S ⁵	..	diphasic	..	upward, then downward.
T ² -S ⁵	..	diphasic	..	upward, then downward.
T ² -S ⁶	..	diphasic	..	upward, then downward.
T ² -A ²	..	diphasic	..	upward, then downward.
S ⁵ -S ⁴	..	not strictly diphasic		upward slight, then downward.

* The heart of Dog B R was the first examined histologically ; in this instance every section was mounted and examined ; a selection was made of those at which an appreciable change in node dimensions was noticeable for purposes of tabulation. In subsequent examinations each twentieth section was examined and those were selected which lay at points of variation, because it was found that the first method offered no appreciable advantage.

Lead.	Curve.	Direction of variation.
S ⁴ -S ² ..	polyphasic ..	upward, then downward.
T ⁶ -T ⁷ ..	monophasic ..	upward.
T ² -T ¹ ..	diphasic ..	upward, then downward.
T ² -T ¹ ..	diphasic ..	upward, then downward.
T ² -P ² ..	triphasic ..	downward, then upward, then downward.
T ² -Lower edge of wound ..	..	P, R, and T directed upward.
Upper edge-lower edge of wound ..	..	duplicate of original control.
T ² -P ² ..	— ..	downward.

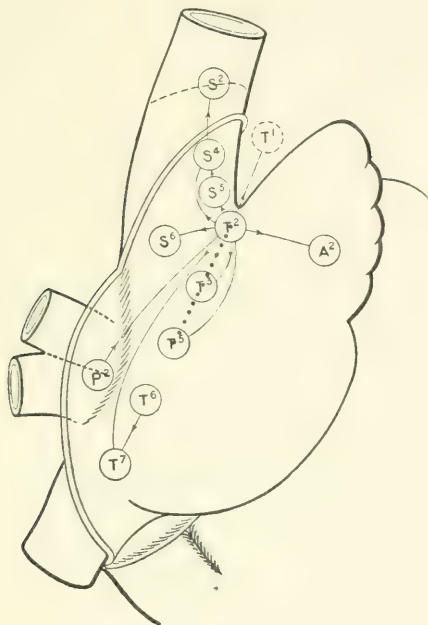


Fig. 3.

A similar representation to those preceding. The additional point T¹ requires explanation. The lead lay on the aortic surface of the auricle, namely, over the cavo-appendicular angle, and on the surface directed towards the aorta in the line of the sulcus.

T² was consequently demonstrated to be primarily negative to all other points in the line of the sulcus terminalis; also to six other points in its vicinity. (T² was not negative to one distant point, namely P², a point within the pericardial sack, overlying a branch of the right pulmonary vein.) Of the outside leads, all showed primary negativity of the point proximal to T².

The points of the leads were marked while the heart lay *in situ*. The heart was excised and preserved for histological examination.

Serial sections 10 μ thick and transverse to the sulcus terminalis were cut, and every twentieth section mounted and stained with hæmatoxylin, followed by Van Gieson's picro-acid fuchsin. The sections were examined in series and a sufficient number were selected for more exact measurement, at such intervals as to give the approximate shape and dimensions of the node.

The node begins about 3 mm. caudal to the cavo-auricular angle and extends for 9.7 mm..

Table giving measurements of S-A node in the heart of Dog B V.

Block, including area.	Distance in mm. from beginning of node.	Cross-section of node at selected intervals.			REMARKS.
		Width in mm.	Depth in mm.	Area in square mm.	
T ²	0.0	—	—	0.0018	Two bits of nodal tissue.
	0.5	0.6 —	0.4 —	0.10 —	
	0.9	0.5 +	0.3 —	0.06 +	
	1.3	0.7 —	0.4 +	0.10 +	
	1.7	0.4 +	0.4 —	0.06 +	
	2.1	1.3 —	0.8 —	0.44 +	
T ³	2.9	1.9 —	0.6 —	0.45 +	
	4.7	1.3 +	0.5 —	0.53 +	
T ³	6.9	1.8 —	0.5 +	0.52 —	Several bits of nodal tissue.
	7.5	0.6 +	0.2 —	0.05 +	
	8.9	—	—	0.03 +	

9.7 mm. = total length of node.

In shape the node resembles a *spindle* cut in half lengthwise, with the flat surface toward the epicardium.

The point of primary activity (base negativity), T², corresponds to the upper part of the bulbous portion of the sino-auricular node.

DOG B X.

Anæsthesia and procedure as in previous experiments.

Leads from upper and lower edge of wound showed P, R, and T directed upwards (*i.e.*, in base-negative direction).

Subsequent leads are tabulated below the accompanying diagram.

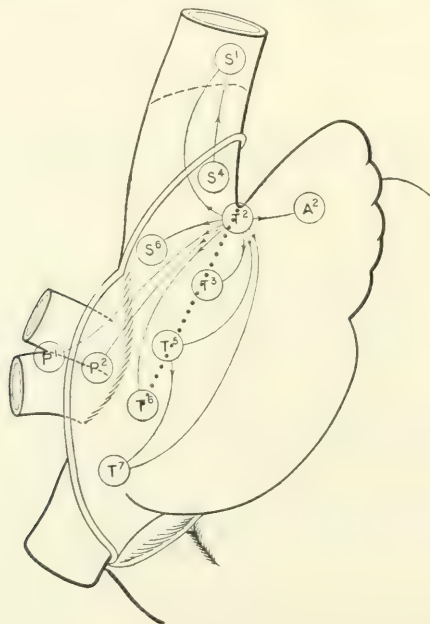


Fig. 4.

Lead.	Curve.	Direction of variation.
T ² -T ⁷ ..	Diphasic ..	Upward,* downward.
T ² -T ⁵ ..	diphasic ..	upward, then downward.
T ² -T ³ ..	diphasic ..	upward, then downward.
T ² -S ⁶ ..	diphasic ..	upward, then downward.
T ² -A ² ..	diphasic ..	upward, then downward.
T ² -S ¹ ..	diphasic ..	upward,* downward.
T ² -S ¹ ..	diphasic ..	upward,* downward.
T ² -S ¹ ..	diphasic ..	upward,* downward.
S ⁴ -S ¹ ..	polyphasic ..	upward slight, downward slight, then markedly upward.
T ⁵ -T ⁷ ..	diphasic ..	upward, then downward.
T ² -P ² ..	not strictly diphasic ..	upward, then downward.
T ² -T ⁶ ..	diphasic ..	upward,* then downward.
Upper edge to lower edge of wound obtained.	showed curves identical with those previously obtained.	
T ² -P ¹ ..	diphasic ..	upward, then downward.

T² was consequently demonstrated to be primarily negative to all other points in the line of the sulcus terminalis; also to other points on the auricle, superior vena cava, and branches of the right pulmonary vein. Of the outside leads, those tested showed primary negativity of the point proximal to T².

The points of the leads were marked while the heart lay *in situ*. The heart was excised and preserved for histological examination.

The histological examination was made in the manner described in the protocol of Dog B V.

The node begins at the cavo-appendicular angle and extends for 20.4 mm..

Table giving measurements of S-A node in the heart of Dog B X.

Block, including area.	Distance in mm. from beginning of node.	Cross-section of node at selected intervals.			REMARKS
		Width in mm.	Depth in mm.	Area in square mm.	
T ²	0.0	—	—	0.01 —	
	4.4	1.1 —	0.2	0.07 —	
	4.8	1.6	0.7 —	0.49 —	
	5.2	1.9 —	0.6 —	0.57 +	
T ³	6.0	1.4 —	0.6	0.40 —	
	8.8	0.8 +	0.8	0.35 —	
T ⁵	11.0	—	—	0.17 —	Node was dipping at this point and broke into two branches.
	14.6	0.8 —	0.4 —	0.13 —	
	16.8	0.9 +	0.2	0.09 —	
T ⁶	18.4	1.0 +	0.2 —	0.08 +	
	19.8	0.4 —	0.1 —	0.01 +	

20.4 mm. = total length of node.

The shape of the node resembles that of a club.

The point of primary activity (negativity), T², lies over the beginning and bulbous portion of the sino-auricular node.

* The upward variation was split at the summit in each instance.

DOG B Y.

Anæsthesia and procedure as in previous experiments.

Leads were taken from the upper and lower edges of the wound, and showed P, R, and T directed upwards.

Subsequent leads are tabulated below the accompanying diagram.

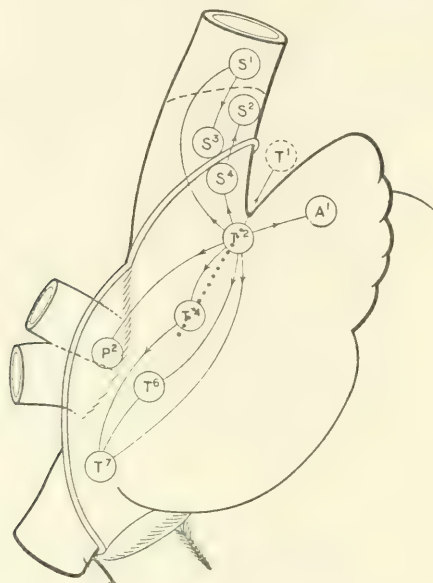


Fig. 5.

Lead.	Curve.	Direction of variation.
T²-T⁷	.. Not strictly diphasic	First variation upward.
T²-T⁴	.. diphasic ..	upward, then downward.
T²-A¹	.. diphasic ..	upward, then downward.
T²-S⁴	.. diphasic ..	upward, then downward.
T²-P²	.. diphasic ..	upward, then downward.
T²-T⁵	.. diphasic ..	upward, then downward.
T⁴-T⁷	.. diphasic ..	upward, then downward.
T⁵-T⁷	.. triphasic ..	downward slight, upward, then downward.
T⁶-T⁷	.. triphasic ..	downward slight, upward, then downward.
T²-T¹	.. diphasic ..	upward, then downward.
T²-lower edge of wound	..	P, R, and T directed upward.
T²-S¹	.. monophasic ..	upward.
S³-S¹	.. diphasic ..	downward slight, then upward.
S⁴-S²	.. monophasic ..	upward.

T² was consequently demonstrated to be primarily negative to all other points in the line of the sulcus terminalis, and also to other points situated on the surface of the auricular appendix, auricle, superior vena cava, and branch of the right pulmonary vein.

Of the outside leads all showed primary negativity of the point proximal to T², except lead S³ to S¹ on the superior vena cava and T⁶-T⁷.

The points of the leads were marked while the heart lay *in situ*. The heart was excised and preserved for histological examination.

The histological examination was carried out in the manner described in the protocol of Dog B V.

The node begins about 1.6 mm. caudal to the cavo-appendicular angle and extends for 16.2 mm..

Table giving measurements of S-A node in the heart of Dog B Y.

Block, including area.	Distance in mm. from beginning of node.	Cross-section of node at selected intervals.			REMARKS.
		Width in mm.	Depth in mm.	Area in square mm.	
T ²	0.0	0.1 —	0.1 —	0.0027	In this experiment no lead was taken in the area between T ² and T ⁵ .
	0.2	0.1 —	0.1 —	0.01	
	1.6	0.6	0.4 +	0.07 +	
	2.0	0.9 —	0.03 —	0.08 +	
	2.6	1.0 +	0.3	0.20 —	
	3.2	1.1 —	0.3 —	0.17 —	
	4.6	2.0 —	0.4 —	0.37 +	
	7.4	1.3	0.2 —	0.16 +	
	9.6	0.6 —	0.2 —	0.05 +	
T ⁴	10.0	1.5 +	0.2 —	0.11 +	Several bits of node.
	11.2	0.8 —	0.1	0.03 +	
	13.0	0.4 —	0.1 —	0.01 +	
	14.8	—	—	0.01 —	

16.2 mm. = total length of node.

In shape the node resembles a *spindle* cut in half lengthwise, with the flat surface toward the epicardium.

The point of primary activity (negativity), T², lies over the beginning and bulbous portion of the sino-auricular node.

DOG B Z.

Anæsthesia and procedure as in previous experiments, except that removal of a portion of the third rib sufficed in this animal.

Leads from the upper to the lower edge of the wound showed P, R, and T directed upward. Subsequent leads are tabulated below the accompanying diagram.

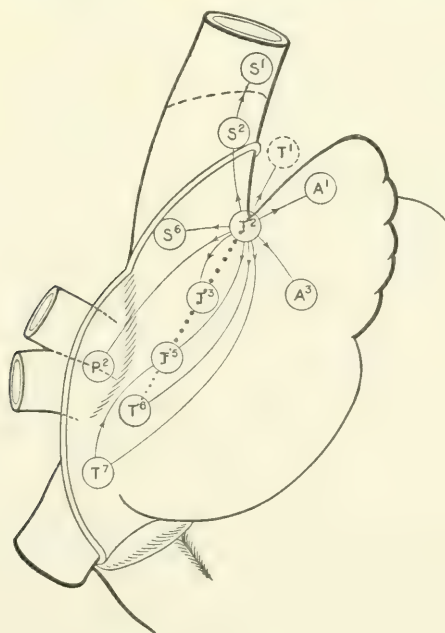


Fig. 6.

<i>Lead.</i>		<i>Curve.</i>		<i>Direction of variation.</i>
T ² -T ⁷	..	Diphasic	..	Upward, then downward.
T ² -T ⁵	..	diphasic	..	upward, then downward.
T ² -T ³	..	diphasic	..	upward, then downward.
T ² -T ⁶	..	diphasic	..	upward, then downward.
T ² -A ³	..	diphasic	..	upward, then downward.
T ² -A ¹	..	diphasic	..	upward, then downward.
T ² -S ⁶	..	diphasic	..	upward, then downward.
T ⁵ -T ⁷	..	triphasic	..	downward slight, upward, then downward.
T ² -P ²	..	diphasic	..	upward, then downward.
S ² -S ¹	..	triphasic	..	upward slight, downward, then upward.
T ² -S ²	..	diphasic	..	upward, then downward.
T ² -T ¹	..	diphasic	..	upward, then downward.

T² was consequently demonstrated to be primarily negative to all other points in the line of the sulcus terminalis, and also to five other points arranged in an approximately circular manner around it. Each of these leads gave a diphasic curve.

Of the outside leads, all showed primary negativity of the point proximal to T², with the single exception of lead T⁵-T⁷.

The points of the leads were marked while the heart lay *in situ*. The heart was excised and preserved for histological examination.

The histological examination was made in the manner described in the protocol of Dog B V

The node begins near the cavo-appendicular angle and extends for 14.8 mm..

Table giving measurements of S-A node in the heart of Dog B Z.

Block, including area.	Distance in mm. from beginning of node.	Cross-section of node at selected intervals.			REMARKS.
		Width in mm.	Depth in mm.	Area in square mm.	
T ²	0.0	—	—	small bits	
	2.0	0.2 +	0.2 —	0.01 +	
	2.4	0.5 —	0.5 +	0.13 —	
	2.8	2.2 +	0.9 —	0.95 +	
T ³	4.8	1.4 —	0.7 ÷	0.49 +	
	6.8	1.8 +	0.3 —	0.20 —	
T ⁵	9.6	bits of node	bits	0.06 —	
	11.2	bits of node	bits	0.01 +	
T ⁶	12.2 to 14.8	bits of node	bits	0.004 —	

14.8 mm. = total length of node.

The general shape of the node resembled that of a *club* cut in half lengthwise, with the flat surface toward the epicardium.

The point of primary activity (negativity), T², lies over the beginning and bulbous portion of the sino-auricular node.

DOG C A.

Anæsthesia and procedure as in previous experiments, except that it was necessary to remove a portion of one rib (the third) alone, in order to get the proper exposure of the right auricle and venæ cavæ.

(1). *Lead* from upper to lower edge of the wound showed P, R, and T directed upwards.

Subsequent leads are tabulated below the accompanying diagram.

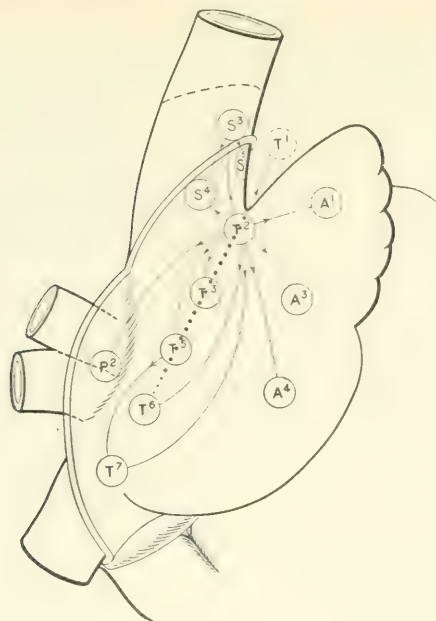


Fig. 7.

	Lead.		Curve.		Direction of variation.
(2).	T ² -T ⁷	..	Diphasic	..	Upward, then downward.
(3).	T ² -T ⁵	..	diphasic	..	upward, then downward.
(4).	T ² -T ³	..	diphasic	..	upward, then downward.
(5).	T ² -A ³	..	diphasic	..	upward, then downward.
(6).	T ² -S ⁴	..	diphasic	..	upward, then downward.
(7).	T ² -T ⁷	..	diphasic	..	upward, then downward.
(8).	T ² -T ⁷	..	diphasic	..	upward, then downward.
(9).	T ² -T ⁵	..	diphasic	..	upward, then downward.
(10).	T ² -T ⁵	..	diphasic	..	upward, then downward.
(11).	T ² -T ³	..	diphasic	..	upward, then downward.
(12).	T ² -T ³	..	diphasic	..	upward, then downward.
(13).	T ² -T ⁶	..	diphasic	..	upward, then downward.
(14).	T ² -A ¹	..	diphasic	..	upward, then downward.
(15).	T ² -P ²	..	diphasic	..	upward, then downward.
(16).	Upper edge to lower edge of wound showed P, R, and T directed upward.				
(17).	T ⁵ -T ⁷	..	—	..	first variation upward.
(18).	T ² -T ¹	..	diphasic	..	upward, then downward.
(19).	T ² -S ³	..	diphasic	..	upward, then downward.
(20).	S ⁴ -S ³	..	triphasic	..	downward slight, upward, then downward.
(21).	T ² -A ⁴	..	diphasic	..	upward, then downward.
(22).	S ⁵ -S ³	..	diphasic	..	downward slight, then upward.
(23).	Upper edge to lower edge of wound showed P, R, and T directed upward.				

T² was consequently demonstrated to be primarily negative to all other points in the line of the sulcus terminalis, and also to six other points arranged around it, and also to a point on the branches of the right pulmonary vein.

Of the outside points, S² on the extrapericardial surface of the superior vena cava, although slightly further removed from T² than either S⁴ or S³, showed primary negativity in respect of these two points.

The points of the leads were marked while the heart lay *in situ*. The heart was excised and preserved for histological examination.

The histological examination was made in the manner described in the protocol of Dog B V.

The node begins near the cavo-appendicular angle and extends for 12 mm..

Table giving the measurements of S-A node in the heart of Dog C A.

Block, including area.	Distance in mm. from beginning of node.	Cross-section of node at selected intervals.			REMARKS.
		Width in mm.	Depth in mm.	Area in square mm.	
T ²	0.0	0.1 —	0.1 +	0.01 —	
	0.6	0.2	0.2 —	0.02 —	
	1.0	1.0	0.4 +	0.24 +	
	1.8	2.3 —	1.2 —	0.87 +	
T ³	3.6	1.3 +	0.9 —	0.58 —	
	4.2	1.4 —	0.9 —	0.51 +	
T ⁵	5.0	1.3 —	0.7	0.35 —	
	6.6	0.9 +	0.8 —	0.19 —	
	8.6	0.6 +	0.2 +	0.05 +	
T ⁶	9.8	0.5 +	0.3 —	0.07 —	Several bits of node. One small bit.
	11.6	—	—	0.01 +	
	11.8	—	—	0.002 +	

12.0 mm. = total length of node.

The shape of the node is that of a *club*.

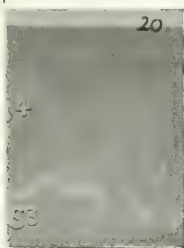
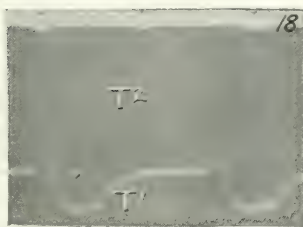
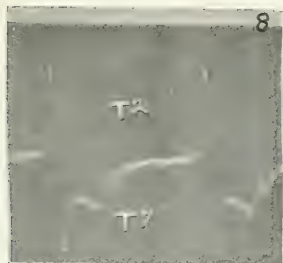
A selection of the actual photographs taken in this particular experiment is given in Fig. 8.

The point of primary activity (negativity), T², lies over the beginning and bulbous portion of the sino-auricular node.

Results and Discussion.

General appearance of the node.—Before proceeding to discuss the observations in relationship to the specialised tissue, which lies near to the superior caval orifice, it will be well to briefly describe the structure as we found it in the hearts of the animals experimented upon. The sino-auricular node is placed beneath the sulcus terminalis and usually extends from the angle formed by the superior cava and free margin of the appendix along the sulcus to the angle of junction of superior and inferior vena cava. It consists of a narrow band of tissue, flat on its superficial or epicardial surface, rounded on its deep surface with the convexity towards the endocardium. In general, it is approximately club-shaped in outline when viewed from its surface aspect. The chief mass of tissue is usually placed in the neighbourhood of the cavo-auricular angle where it lies just beneath the surface of the epicardium. Its termination is not clearly defined, but tapers away. As it is traced in the direction of the inferior vena cava, it diminishes in size until it thins out into a fine and often broken thread, the end of which is more deeply placed and approaches the endocardium. While this has been found to be the more usual configuration, the bulbous portion of the node is not uncommonly less restricted to the cephalic

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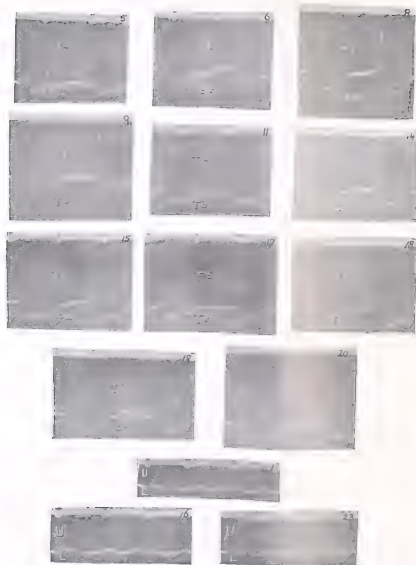


Fig. 5.

termination, but the area of greatest cross-section lies somewhat more removed from the cavo-appendicular angle; this type has been referred to in the protocols as the spindle form of node. The width of the node may be appreciable even at a lower level, but where this occurs the tissue is more shallow.

Relation of the primarily negative point to the bulbous portion of the node.—In the seven hearts* described the separate leads yielded strikingly constant results. Contact T² has been found to be primarily negative to all points on the sulcus terminalis, to a circle of points arranged around it, and to numerous other points on the superior vena cava, appendix and main mass of the auricular tissue, in every observation without exception. On one occasion we found a point upon the right pulmonary vein which was primarily negative to T², but in all other hearts in which this point has been investigated the contrary has been the case, for T² has been primarily negative to this point. We are at a loss for an explanation of this solitary exception.

As a result we are in a position to state, basing our statement upon the current view that primary negativity represents primary activity, that in seven experiments primary activity was manifested in the right auricle at a point (T²) situated at the cavo-appendicular angle, or in its immediate neighbourhood. The histological examination of this area has shown that T² invariably lay directly over the sino-auricular node, and that in all experiments it lay upon or within a few millimetres of the main collection of this tissue, that is to say of the bulbous extremity which we have noted at the cephalic end of the sulcus. The relationship of the contact showing primary negativity to this portion of the node has been absolute in five of the seven experiments; the deviation has been slight in two experiments.

The anatomical and experimental findings convince us that there is far more than a coincidental relationship between them, and we regard the experiments as strongly confirmatory of the view expressed by Keith and Flack that the heart-beat originates in the tissue described by them.

A further and more exact localisation seems possible, and we are inclined to the view that the heart rhythm originates in that portion of the node which lies towards the cavo-appendicular angle, in the neighbourhood of which the bulb occurs. We are supported in this view by the observation that the tissue composing this region of the node in the animals examined has shown a differentiation from the remainder. We find the muscle fibres more deeply staining, arranged more irregularly in network fashion and less vacuolated than the lighter stained, more parallelly arranged and more vacuolated fibres of the remainder of the node.

We may now consider more fully the observations recorded in Wybauw's preliminary note. While we are not in possession of the detailed

* Primary negativity of T² has since been demonstrated in two additional and later experiments.

statement of the method employed, we gather from his note that he finds the first point of negativity at a point on the sulcus, and that almost invariably it is present at a point midway between the cavo-appendicular angle and the angle formed by superior and inferior vena cava. The results which we now report consequently agree in the main with those outlined by Wybauw; in both series of observations the point of primary negativity is discovered on the sulcus terminalis. The divergence consists in the fact that Wybauw places the point of primary activity most commonly near the midpoint of the sulcus terminalis (in the vicinity of T^3 and T^1 in our terminology); whereas we have encountered it at a point (T^2) somewhat more cephalic in direction, a point which we have ascertained, by histological examination of the hearts experimented upon, to overlie the cephalic end of the node.

Outlying leads.—Our observations have been sufficiently numerous to permit us to draw a definite conclusion in regard to the situation of the pacemaker of the dog's heart. During the course of the experiments a number of outlying leads, leads in many of which the points of contact lay in a radial direction to the primarily negative point, have been adopted. Both in the line of the sulcus terminalis and on the superior vena cava, these leads have usually shown the point proximal to the pacemaker to be primarily negative, as compared with a point more distally placed.

Of eight such leads taken on the superior vena cava, five have shown primary negativity of the point nearest T^2 . In the case of the remaining three curves there has been a slight primary deviation indicating negativity of the distal point, but the main variation has been in the opposite direction (as, for example, Curve 20, Fig. 8). Of seven observations upon the caudal end and in the line of the sulcus terminalis, five have shown primary activity of the proximal point, two have shown primary negativity of the distal point; but as in the instance of the superior vena cava, the unexpected deviation has been slight, while the main deviation has been in the contrary direction.

The observations are too few to allow of definite conclusions as to the direction taken by the contraction wave in the auricle, but it appears that in at least the majority of instances the direction of contraction is radial to the pacemaker. Whether in the exceptional instances of slight deviation, indicating primary negativity of a distal point, we must conclude that such a deviation indicates previous primary activity, at this distal point, we are not in a position to judge.

Summary.

Our observations were undertaken with a view of determining with greater accuracy than has hitherto been possible the site of the *primum movens* or so-called pacemaker in the normally beating heart of the dog.

In this animal it has been found that of all the points on the superficies of the right auricle, a point which lies upon the sulcus terminalis of His, and in the immediate neighbourhood of its upper extremity, close to the cavo-auricular angle, is the site of primary activity. It has been compared with numerous points in the line of sulcus terminalis, auricle and superior vena cava.

In the same animals the structure and situation of the sino-auricular node has been carefully examined, and it has been ascertained that the point of primary negativity lies in all instances directly superficial to this tissue. Further, it has been found that the point of primary negativity appears to maintain a fairly definite relationship to an enlargement situated toward the cephalic extremity of the node, lying generally directly over the latter. That portion of the sino-auricular node over which the primarily negative point is found differs structurally from the remainder.

The experimental portion of this work was conducted by two of us (T. L. and B. S. O.) at the University College Hospital Medical School; the histological preparation of the hearts and the reconstruction of the nodes was carried out by two of us (A. O. and B. S. O.) in the laboratory of the Royal College of Surgeons, and we wish, therefore, to express our indebtedness to Professor Keith, the Conservator of the Museum.

CONCLUSION.

The so-called pacemaker in the dog is located at the upper or cephalic extremity of the sino-auricular node.

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- ⁶ LEWIS. *Heart*, 1909-10, i, 306.
- ⁷ WYBAUW. Bull. d. l. Soc. Roy. d. Sc. d. Brux., 1910, No. 5.

A CASE OF PAROXYSMAL TACHYCARDIA.

BY ALFRED E. COHN.

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RECORDS of cases of true paroxysmal tachycardia which show changes in rate and rhythm within the space of one or two cardiac cycles are still sufficiently scarce to make it of interest to report the history and physical signs of another case. Two varieties of this type of arrhythmia have been distinguished: one in which the increase in rate follows increased stimulus production at some level in the auricle and in which during the paroxysm auricular contraction can always be demonstrated as preceding the ventricular by at least the normal interval; and the second type in which auricles and ventricles seem to beat together, in response to impulse formation between them, now called the nodal type. Of the auricular type, Lewis¹ was able to collect two cases reported by Schmoll, one by Hirschfelder, one by Hay, one by Cowan, McDonald and Binning, and finally two by himself, to which he subsequently added another;² eight cases in all.

W. A., 39 years old, a tramway conductor, has been married seven years. He is the father of five children, one of whom died in infancy. A brother died at 21 of "mitral disease." He has had measles, whooping cough and chicken pox, but no other acute infection. Occasionally he suffers from coughs; he has no pulmonary disease. For a number of years he has been subject to dyspepsia, of which the main symptom has been heart-burn. Ten years ago he had gonorrhœa, and at about the same time admits having had a soft chancre, which was cauterised and for which he took pills, but for which he received neither inunctions nor injections. Four years ago an eruption appeared, which he describes as consisting of white blotches on both hands and forearms. In view of the vagueness of these signs, the question of syphilitic infection must be left open. During his recent stay in the hospital, he suffered from osteitis of the nasal bones, accompanied by fever and thought to be syphilitic. Two complement-fixation tests were negative.

For 20 years he has had seizures which consisted of palpitation, dyspnœa, and a sensation of choking; they would last 15 to 20 minutes and were relieved by his lying down. He never had headaches, vertigo, convulsions, syncopal attacks or pain. A few minutes after the cessation

of an attack he was able to resume work. There have been no symptoms referable to the eyes or ears, nor any sensation which might be termed aural. His appetite has always been irregular; his bowels always constipated. He complains of flatulence and has noticed that with the passage of flatus the pulse-rate becomes slower. Not only have I noticed this phenomenon, but also a similar one after the eructation of gas. He recognises the onset of the attacks by the occurrence of palpitation and a sensation of tapping in the temporal region; the offset is marked by the disappearance of this sensation.

The present seizure is the longest he has had. In September, 1909, he began to be treated for the nasal suppuration already noted. While under treatment for this condition the present attack commenced. He was seized while on the platform of a station and was obliged to stop there an hour and a quarter. The tachycardia persisted until he was admitted to the hospital.

When he first entered, December, 1909, the tachycardia occurred in phases lasting from 30 seconds to two hours. Gradually, and after prolonged rest in bed, the tachycardial periods became shorter and those of relative bradycardia longer. Then days succeeded, in which few periods of tachycardia could be found, but during which the pulse was frequently irregular. Finally the heart action returned to a normal rate and rhythm. The nasal suppuration improved and the patient was discharged on February 10th, 1910. He has since had (about April 1st) one attack of tachycardia lasting approximately a half hour. The nasal suppuration still continues. In addition he has an oedema of his left leg, attributed to thrombosis of its veins.

The man was a well-nourished, well-developed adult. No abnormality was observed apart from the nasal osteitis and the attacks of tachycardia. The heart was normal in size and there were no murmurs. From December 7th to 19th, fever ranging from 100° to 102° F. was present. From the 19th to 21st, the temperature reached 104° or 105° in the afternoon. Later it fell to 100° to 102° , and from January 2nd, 1910, onwards it remained normal. By the middle of December the attacks of tachycardia had become infrequent and the normal rhythm was disturbed only by extrasystoles.

Beginning on January 17th, he was given deep injections of mercuric bichloride, $\frac{1}{8}$ grain, every other day, and received potassium iodide in increasing doses up to 144 grains. The anti-specific treatment was not commenced until after the temperature was normal. The urine was always normal.

Two curves (Fig. 1 and 2) are reproduced to indicate the relationships of paroxysms. To the right of the ordinate, in Fig. 1, a complete paroxysm is shown between two periods of slower rate; to the left, an interval between two paroxysms. The rate during the paroxysms is approximately 200; at times 186 beats have been counted to the minute, at other times 210;

during the slow periods it ranges from 90 to 110, being usually about 100. In Fig. 2 the slow rate is estimated at 92, the paroxysmal rate at 200. As has been frequently shown, there is no simple mathematical relationship between the rates of the slow and fast rhythms. A feature of the tracings, observed on several occasions, is the occurrence of marked alternation (end of Fig. 2); it is so marked at times that but a faint indication of the alternate waves is seen in the radial curves.

The difficulty in the interpretation of certain of the tracings lies in determining the beginning of ventricular systole in the radial curve; the rapid rate and the fact that, when it can be seen, marked diastole is the rule, complicates the picture. A comparison of the radial wave, marked *x* in Fig. 4, and the cycles at the end of the paroxysm in Fig. 2, render the interpretation clearer. The point representing the beginning of ventricular systole often rides up close to the summit of a radial wave. The synchronous point in the venous curve is at the upstroke of the tall wave. The majority of the *c* points can be fixed with accuracy, and it remains to determine the points of incidence of auricular contraction. The waves, marked *a* in Fig. 1, cannot be attributed to ventricular systole alone; they are too prominent, for the radial beats accompanying them are small. Auricular contraction is the only other factor which could assist in the production of waves of such amplitude. The large waves are therefore attributed to synchronous auricular and ventricular beats, and are taken to be atrio-ventricular in origin. Additional support for the view that they are not dependent upon ventricular contractions alone is found in the absence of alternation which is so marked a feature in the radial curve of the second paroxysm (Fig. 2), and in the paroxysm to the left of the coincidence marks in Fig. 1. This interpretation brings the case into line with that described by Rihl,⁴ and by Lewis,³ and forms the third case of the group.

The slowing and subsequent acceleration of the sinus rate after a paroxysm, pointed out by Lewis, is shown in Fig. 2, where the unusual length of the post-paroxysmal pause should also be noted. Its duration is $\frac{5.8}{5}$ here, though its usual length is $\frac{4.3}{5}$. The average post-extrasystolic pause is $\frac{3.9}{5}$. Here, then, as in the case described by Lewis, the post-paroxysmal is slightly longer than the post-extrasystolic pause.

Fig. 1. The uppermost line in this and the subsequent figures shows the time in 0.2 sec.. The second line is the venous (jugular) curve; the lowest line is taken from the radial artery. To the left of the ordinate is a stretch of curve showing a slow period between the offset and the onset of a paroxysm; to the right, a paroxysm between two stretches of slow rate.

Fig. 2. The offset of one and the onset of a second paroxysm are shown. The post-paroxysmal pause is $\frac{4.8}{5}$ sec., the slowly increasing sinus rate during the slow period and alternation in the radial curve are also shown. Rate of the slow period, 92.3; rate during paroxysm, 206.2. December 8th, 1909.

Fig. 3. At the beginning of the figure are successive paired groups; normal cycles followed by extrasystoles. The *a-c* interval is 0.15 sec.; the *a'-c'* interval, 0.25. An alternative interpretation is inserted between the jugular and radial curve. December, 1909.

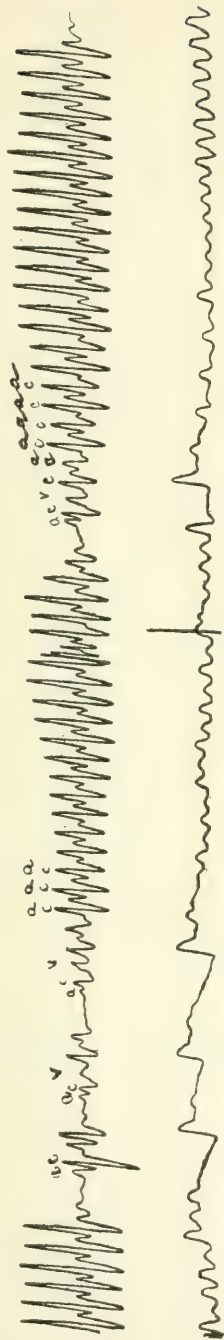


FIG. 1.

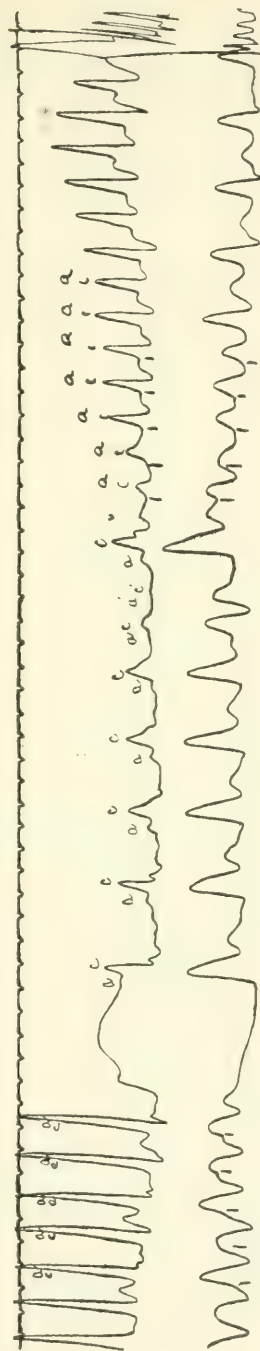


FIG. 2.

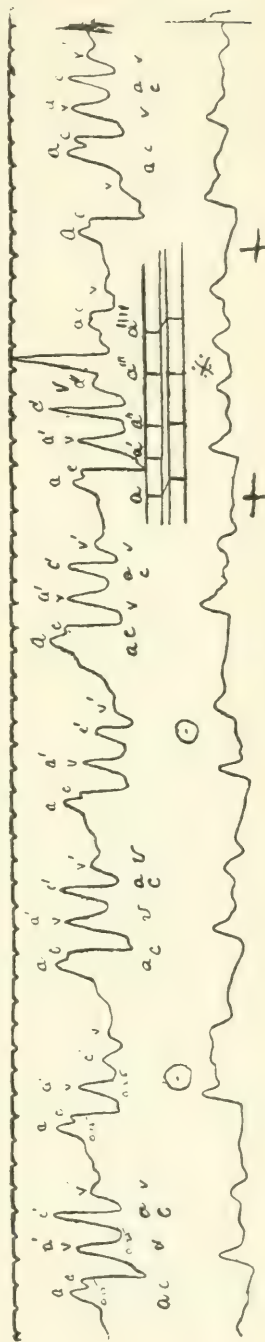


FIG. 3.

After the first days in the hospital, periods occurred in which slower rhythms began to predominate. In the slower rhythm a mechanism was presented of a nature different to that of the paroxysms themselves. Single and multiple extrasystoles occurred, and are shown in Fig. 3, 4, and 5. In Fig. 3 and 5 all the irregularities, with the exception marked \times in each, show groups of two beats each consisting of a normal sequence and an extrasystole. In Fig. 4 the irregularity consists of a systole with two extra-contractions. The exceptional periods, marked \times in Fig. 3 and 5, offer special difficulties.

The groups marked \odot in Fig. 3 and 5 receive a simple explanation. In each case a' is superimposed on v , and is followed by the corresponding c' and v' . The c' wave is of a height compatible with its representative in the radial curve. There is a bigeminy of auricular extrasystoles. It is supposed that a' falls with the upstroke of v , and that the $a'-c'$ interval is prolonged from 0.15 sec. to 0.25 sec.. In the paired groups (Fig. 3) other than those marked \odot , the c' wave is more conspicuous than the elevation of the corresponding radial wave would lead one to expect. Whether a respiratory influence is responsible for this cannot now be determined. It might be assumed, as in the paroxysmal phases, that a coincident auricular contraction has been responsible for the exaggeration, and we are dealing with an atrio-ventricular or with an additional and blocked auricular extrasystole. In any case it should be noted that the v_c^a interval is the same as the $a'-c'$ in the extrasystole marked \odot (Fig. 3). Further, it may be urged that the v wave before c_c^a (atrio-ventricular) wave is about as tall as that in the group marked \odot , where a' is surely imposed upon it.

A tentative interpretation is given of Fig. 4 in the lettering. If the curves in this figure are compared with the groups \odot in Fig. 3 a similarity will be observed between the normal systoles and the first extrasystoles in both. The lengthening of the $a'-c'$ interval is also noticeable. The wave c'' (Fig. 4) is out of all proportion to c and c' and to both the systolic and the extrasystolic waves in the radial curve. On this account an alternative reading is inserted between the venous and radial curves in Fig. 4. In the first cycle diagrammatised, a , c , and v waves appear. With v of this cycle falls a' of the second cycle; c' falls just before a'' , which is blocked; while the tall peak represents the coincident contractions of auricle and ventricle and is a combined a''' and c''' (an atrio-ventricular extrasystole). The interpretation is in any case problematic.

Fig. 4. Shows successive groups of three members each, a systole followed by two extrasystoles. The $a-c$ and the $a''-c''$ intervals are 0.2 sec., the $a'-c'$ is 0.28 sec.. An alternative interpretation is inserted. December 12th, 1909.

Fig. 5. The points marked \odot show normal cycles followed by single extrasystoles; that marked \times shows two, if not three, extrasystoles after the primary contraction. See Fig. 3 \times . December 17th, 1909.

Fig. 6. Taken on the same day as the preceding curve. The rate and sequence of the heart is normal. Given for comparison with preceding figures. December 17th, 1909.

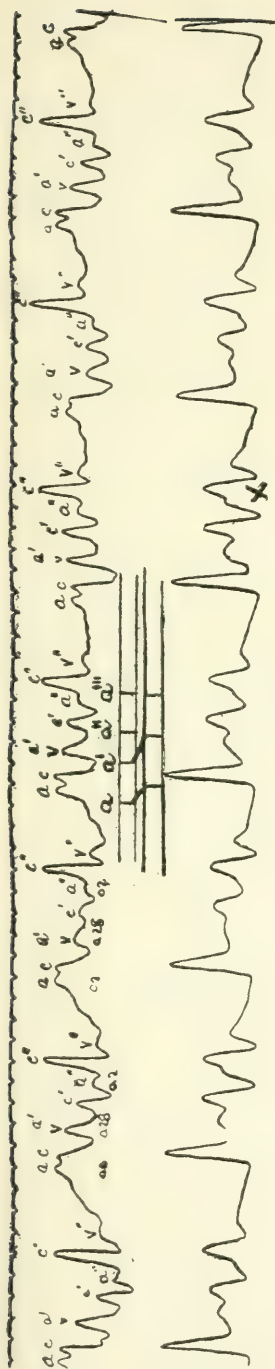


FIG. 4.

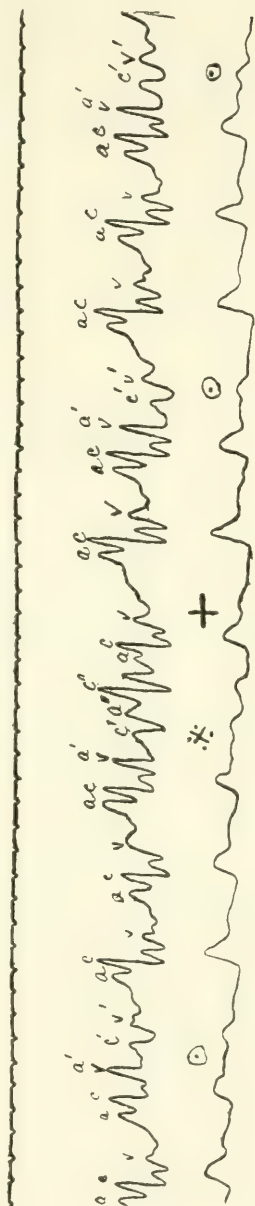


FIG. 5.

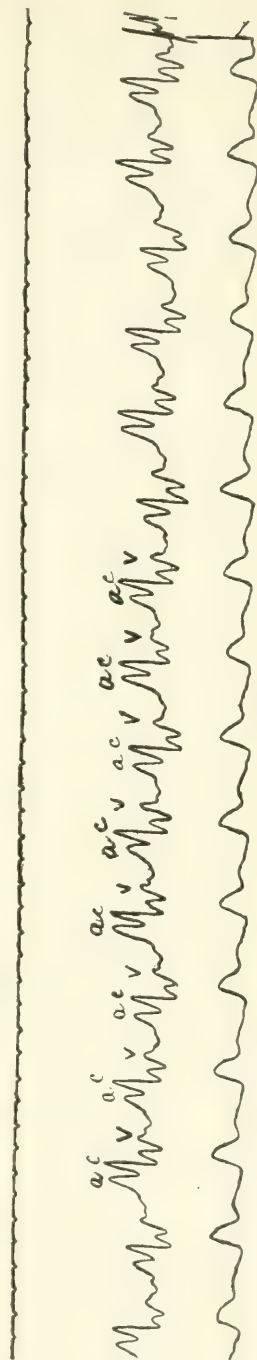


FIG. 6.

Fig. 3 and 5 ✕ offer special difficulties, and likewise on account of the discrepancy between the tall waves in the venous and the corresponding small ones in the radial curves. An alternative interpretation has been inserted between the curves of Fig. 3, and will be seen to be similar to that inserted in Fig. 4. A difference between the two is seen in that there is no pause after a''' in Fig. 3, while considerable ones exist in Fig. 4. It is followed by a wave a'''' , and this is succeeded by a pause (marked +) equal to that succeeding the extrasystole marked + at an earlier period. The pause indicates the probable extrasystolic nature of a'''' . A somewhat similar instance is seen in Fig. 5 ✕, where the cycle +, the last of the group (it is preceded by a shortened pause), is longer than the normal cycles in this figure. A consideration of the facts forces us to acknowledge the possible occurrence of true nodal extrasystoles as successors of auricular extrasystoles. That this condition may occur has been shown by Lewis³ (curve 26).

Considering the evidence derived from the paroxysmal phases and the slower (sinus) periods, the conclusion that the case under consideration is one of paroxysmal tachycardia of atrio-ventricular origin seems justified; it is not dissimilar to two other cases previously recorded: one briefly by Rihl⁴ and one in detail by Lewis.³ Of the phenomena already noted as associated with paroxysmal tachycardia, this case also shows a lengthened post-paroxysmal delay; increasing sinus rate thereafter; increasing pressure in the venous curve at the onset of the paroxysms; and lastly an absence of a simple mathematical ratio between fast and slow heart rates.

It is with pleasure that I acknowledge my indebtedness to Dr. N. E. Brill for the privilege of describing this case.

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AURICULAR FLUTTER AND FIBRILLATION.

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METHOD OF EXAMINATION.

The sensitiveness of the instrument.

The following research upon the human electrocardiogram has been carried out by means of the Cambridge model of Einthoven's string galvanometer. The form of curve obtained from the heart varies as the conditions under which it is recorded are varied and depends upon the construction of the instrument employed, the strength of magnetic field, tension of moving conductor, etc.. For accurate interpretation and comparison with results obtained by other observers it is therefore essential that close attention be paid to the capacities of the particular instrument used and its adjustment. In the galvanometer employed the electromagnet is wound with thick wire of small resistance through which is passed a current of 9 Ampères derived from a battery of accumulators. The constant current supplied by the City of Edinburgh was at first made use of and answered well for the purpose of electrocardiogram registration. Such a current is, however, liable to slight fluctuations, which under certain conditions may interfere with results and for greater accuracy a battery of accumulators has been substituted. A stream of cold water is passed through coils of lead tubing surrounding the magnet in order to obviate the changes in tension of the string which would be caused by the heating effects of the magnet circuit. The image of the silvered quartz fibre is projected with a magnification of 820 diameters by the light of a Siemens and Shuckert arc lamp of 20 Ampères upon a cylindrical lens. Behind the lens is the horizontal slit whose breadth may be increased or diminished in accordance with the speed given to the carrier of the photographic plate. The plate is drawn up vertically behind the slit by means of a piston working in an oil cylinder when slow and intermediate rates of movement are desired. For the rapid rate, which is necessary to measure the deflection time of the string in control curves, the carrier is shot across the slit by means of a spring. The projecting system consists of a Zeiss achromatic objective *A A* used as condenser, apochromatic objective of 16 mm. focus and compensating eyepiece No. 12. An alum bath with parallel glass sides is placed before the projecting microscope to diminish the heating effect of the light.

The arrangement of the compensating circuit is similar to that used by Einthoven. The circuit from an accumulator charged to indicate 2 Volts is passed through a Siemens resistance box in which is placed 20,000 Ohms and also through a dial rheostat from which a derived current enters the

galvanometer circuit. Before introducing the electrodes and subject into the galvanometer circuit a large resistance is placed in series with the string. Any difference of potential is then compensated roughly and on diminishing and finally removing the series resistance exact compensation is obtained. The sensitiveness of the instrument is then adjusted by altering the tension of the string until a deflection of the desired number of millimeters is caused by a known difference of potential introduced by the dial rheostat.

The electrodes are of the form commonly employed for electrocardiograms and consist of glass jars containing a saturated solution of zinc sulphate, in which lie amalgamated zinc plates, and porous jars filled with salt solution in which the hands or feet of the subject are immersed. The apparatus is so arranged that the electrode taking the potential of the base of the heart or right ventricle is connected with the lower end of the string. A current downwards through the string gives rise to a deflection upwards on the photographic plate.

The resistance of the subject is measured by substituting for him a resistance box and introducing resistance until the deflection to a known difference of potential is the same as that obtained with the subject in the galvanometer circuit. In some cases Kohlrausch's telephone method has been employed.

The resistance of the string is 5,000 Ohms.

Some idea of the sensitiveness for weak currents of the particular instrument employed may be obtained from Fig. 10 which records the deflection given with a current of 2.2×10^{-10} Ampères. The time-marker indicates seconds and the vertical lines which are produced by a rotating toothed disc and are not regularly timed, shew the direction of the slit. The deflection time is long, amounting to many seconds. 1 mm. ordinate represents about 3.4×10^{-11} Ampères, and fractions of a millimeter may be estimated. The irregularities on the curve which coincide with the vertical lines are due to alterations in the tension of the string brought about when it is in a relaxed condition by variations in temperature accompanying the periodical shadowing of the light as the teeth of the rotating disc pass in front of the projecting microscope. Such irregularities may be overcome by using a light filter of copper ammonium sulphate.

In recording by means of the string galvanometer, a curve such as the electrocardiogram, in which rapid alternations of current are present, it is important to consider the tension to be given to the string, for upon this the sensitiveness and time of deflection depend. As the string is relaxed the deflections become slower and if these are less rapid than the oscillations of the current to be measured the curve will not render the latter accurately, and to obtain a true picture a curve must be calculated as is done in the case of the capillary electrometer from the properties of the particular instrument employed and the details of the directly recorded curve. It is therefore necessary, if trustworthy data are to be collected, to impart to the string such a tension that the various summits of the electrocardiogram will appear

undistorted, or if greater relaxation is used, to measure and record the deflection time of the instrument at the sensitiveness employed in order that the results may be compared with those obtained by other instruments.

The sensitiveness of the string galvanometer in Leyden—the original instrument—is so regulated for the study of the human electrocardiogram that, with a magnification of 660 diameters a difference of potential of 1 millivolt introduced into the circuit containing galvanometer and subject, or resistance box substituted for him, gives a deflection of 10 mm.. The records so obtained have been compared with the calculated curve of the capillary electrometer \bar{r} and found to be closely similar. The summits *P*, *Q*, *R*, *S* and *T*, are present in both curves and have the same relative height. The galvanometer curves recorded by the instrument so regulated present fairly accurately the variations of potential occurring at the electrodes, although some slight correction is necessary for the high and steep summit *R*, and students of the electrocardiogram very generally, where details of control curves are published, have used a sensitiveness such that 1 millivolt equals one centimeter. This does not, however, in itself permit of exact comparison between results obtained from different instruments, since, apart from variations in strength of magnetic field, etc., the electrical resistance of the subject varies.

Samojloff⁷² has published electrocardiograms photographed under varying conditions of tension of string and strength of magnetic field, accompanied by control curves taken with a rapid rate of plate carrier, so that the deflection time can be accurately determined in the several cases. It is shewn that the curve presents all the summits when the deflection time is 0.024 second. When the tension is diminished so that the control deflection becomes twice as great the deflection time becomes 0.06 second. The summits of the electrocardiogram are then in general higher, especially *T*, but the deformation of the curve is evident from the fact that summit *S* is no longer visible.

In Fig. 11 is reproduced an electrocardiogram of a healthy heart chosen at random and not because it is specially typical,—the curve from healthy hearts exhibiting considerable variation in form—where the sensitiveness of the string has been so regulated that 1 millivolt corresponds, with a magnification of 820 diameters, to a deflection of 12 mm.. The current has been led off from the two hands, that is to say Einthoven's derivation *I* has been adopted. Fig. 12 gives a control curve where 1 millivolt has been introduced into the galvanometer circuit under the same conditions as to resistance and tension as obtained in Fig. 11. The speed of the carrier is 840 mm. per second. In order to obtain a distinct record with the rapid speed of plate the magnification has been reduced to 580 diameters. The deflection time is found to be 0.022 second. It is therefore possible to increase the sensitiveness of the instrument further and still to obtain, as Samojloff has shewn, a trustworthy record of the electrical changes.

The tone of skeletal muscles.

In Fig 11 it will be observed that in addition to summits representing auricular and ventricular action, and superposed upon them, there are present rapid small deflections. These are not to be attributed to shaking of the instrument or other mechanical imperfection. They are visible to a greater or less extent in all human electrocardiograms and must represent electrical changes occurring in the body. In one instance while the electrocardiogram was being recorded from a patient in this Laboratory he fell asleep. The small deflections which had before been marked were found to be imperceptible during sleep. The use of a narcotic has been shewn to abolish these deflections, which are very distinct in the electrocardiogram of the dog recorded in the usual way¹¹. The deflections are not regular in rate and it is difficult to measure their frequency accurately. The rate appears to be on an average about 60 to 70 per second. The summits give the impression of splintering, and in parts of the curve where they are less broken there seems to be evidence of a slower more regular rhythm of about 40 to 50 per second. Piper⁶⁷ has found in the string galvanometer curves of the response of the flexors of the forearm on voluntary contraction a remarkably constant rhythm of 47 to 50 per second.

Miss Buchanan¹ using the capillary electrometer finds a higher rate than this, about 100 to 140, but emphasises the fact of the irregularity of the rhythm measured. In one case, where the electrical effect was exceptionally strong and regular, records were obtained which exhibit a frequency of 56 and 52 per second. Dittler,⁶ who investigated the response of slips of the diaphragm to impulses from the respiratory centre and measured the rhythm of the deflections where these appear most regular, finds them to occur at a rate of 60 to 70 per second.

It is probable that the small deflections in the electrocardiogram are the expression of the tone of the skeletal musculature, and as we are dealing with the combined effect of many groups of muscles the observed irregularity is due to superposition and interference.

AURICULAR FLUTTER IN THE HUMAN HEART.

Clinical Features.

When there is a lesion completely severing the auriculo-ventricular bundle of the human heart, the auricles usually contract rhythmically about sixty to eighty times per minute. There are, however, three cases of auriculo-ventricular heart-block on record in which there was a pronounced auricular tachycardia. The first case (J. K.) is that which was recorded by one of us⁷⁰ in 1905, and also by G. A. Gibson^{21, 22} in 1905 and 1906. This case is recorded more fully in the present paper. The second case (G. D.) was described by

G. A. Gibson²² in 1906. The rate of auricular contraction was at first 168 per minute, but, as is shewn in one of the tracings, it subsequently rose to about 350 per minute. In the third case, recorded by Hertz and Goodhart,³² the rate of the auricles was almost constantly about 234 per minute, and that of the ventricles about 80 per minute. The auricular beats were absolutely rhythmic, and were considered to be genuine auricular, and not so-called fibrillary, contractions. Two cases of auriculo-ventricular heart-block associated with auricular "fibrillation" have been described by Lewis⁴⁸ (*CASE XII* of his series), and by Lewis and Mack.⁴⁹ In cases of paroxysmal tachycardia we know that the rate of the heart's contraction may exceed 250 per minute. This rate was recorded in the case described by Lommel,⁵³ while in the case recorded by James³⁸ the rate was sometimes 260 per minute, and in one of Hay's²⁴ cases the rate varied from 160 to 300 per minute.

CASE I. (J. K.) which we now record is that of a man, aged sixty-one, who has been under the observation of one of us for six years, and who had previously manifested the phenomena of the Adams-Stokes syndrome. When he was first seen, he presented the ordinary clinical features of complete auriculo-ventricular heart-block, the rate of auricular contraction varying from 50.7 to 70.5 per minute, while the ventricular rate varied from 31.1 to 35.7 per minute. The auricles beat rhythmically, and the ventricular contractions were likewise rhythmic. Tracings taken in 1904 and 1905 have been published elsewhere by G. A. Gibson^{21, 22} and by one of us.⁷⁰

In June, 1905, the rate of auricular contraction increased to 65.8 per minute, and a slight degree of auricular irregularity was observed. The patient was then given $\frac{1}{100}$ grain of atropin sulphate thrice daily for three days, and on the third day (23rd June, 1905) the auricular rate was found to be 273.03 per minute, and the ventricular rate 34.88 per minute. On the same day, ten minutes after $\frac{1}{6}$ grain of atropin sulphate had been given subcutaneously, the auricular rate was 274.73, and the ventricular rate 36.58 per minute. The administration of atropin was stopped on the 27th June, yet in tracings taken three days later the auricular rate was 275.5 and the ventricular rate 30.0 per minute. On the 8th July the auricular rate was 270.77, and the ventricular rate 30.77 per minute. In the absence of graphic records we cannot say how long the rapid auricular flutter lasted at that time; but three months later when tracings were again obtained the auricular flutter had not only entirely disappeared, but had given place to an auricular bradycardia, for the auricles were beating rhythmically 43.7 times per minute, while the ventricular rate was 31.57 per minute. Eight months later, in June, 1906, the auricular flutter was again recorded, and the rate was as high as 300.0 per minute. In May and August, 1908, the auricular rate had again fallen to 53.57 beats per minute. On every occasion, however, on which the patient has been examined since November, 1908, the auricular flutter has been constantly present, the lowest rate being 234.63 in August, 1909, and the highest rate recorded by mechanical registration being 291.89 in November, 1908. The beats are almost absolutely

rhythmic, and their rate is not materially influenced by exercise, atropin, digitalis, or bilateral pressure upon the vagi. The following table shews the auricular and ventricular rates during the last five and a half years. On only two occasions since November, 1908, has the auricular rate fallen below 250 per minute.

		RATE PER MINUTE.		
		Auricles.	Ventricles.	
1905	26th March	64.78	33.80	Both auricles and ventricles are beating rhythmically.
	16th April	70.5	32.9	
	30th April	66.8	35.7	
	19th May	50.76	32.30	Auricles slightly arrhythmic.
	2nd June	—	—	Syncopal attack. Fell from ladder.
	9th June	65.8	31.14	Auricles somewhat arrhythmic.
	16th June	60.71	32	
	19th June	—	—	Examined by Röntgen rays. Auricles beating 60 time per minute.
	20th June	—	—	Patient began to take $\frac{1}{100}$ grain of atropin sulphate thrice daily.
	23rd June	273.03	34.88	
		274.73	36.58	Ten minutes after $\frac{1}{80}$ grain of atropin sulphate.
	27th June	—	—	Atropin stopped.
	30th June	275.5	30.0	Both auricles and ventricles are beating rhythmically.
	8th July	270.77	30.77	
	14th October	43.70	31.57	
1906	3rd June	290.90	32.96	
		300.00	33.80	
1908	28th May	57.39	31.30	Five minutes after bilateral pressure upon vagi. Ventricles are arrhythmic.
	25th August	53.33	33.60	Both auricles and ventricles are somewhat arrhythmic.
	19th November	291.89	33.61	Both auricles and ventricles are rhythmic.
		272.72	33.33	
		267.85	34.09	
	21st November	272.72	33.33	
1909	22nd February	268.75	35.29	A few ventricular extrasystoles.
	8th March	255.55	42.85	Both auricles and ventricles are rhythmic.
	28th July	260.86	31.91	
	19th August	262.5	33.3	After bilateral pressure on the vagi.
		257.0	34.2	After exercise.
	20th August	234.63	31.91	Both auricles and ventricles are rhythmic.
	25th August	—	56	Group-beating of ventricles.
	26th August	252.63	34.42	A few ventricular extrasystoles.
	20th September	276.9	32.4	Both auricles and ventricles are beating rhythmically.
	30th September	261.11	56.7	Group beating of ventricles.
	4th October	260.86	58.9	
	9th October	268.1	41.02	10.30 a.m. Ventricular arrhythmia.
			41.74	10.40 a.m.
				10.51 a.m. $\frac{1}{60}$ grain of atropin sulphate, subcutaneously.
		263.8		10.56 a.m.
			44.21	10.57 a.m.
			44.6	11.3 a.m.
		268.6	44.44	11.11 a.m.
			48.2	11.12 a.m.
			45.2	11.19 a.m.
		260.8	44.0	11.27 a.m.
	14th October	272.7	51.5	Group-beating of ventricles. Has been taking digitalis for five days.
	13th November	—	—	Ventricles beating rhythmically.

		RATE PER MINUTE.		
		Auricles.	Ventricles.	
	22nd November	251.18	63.15	Group-beating of the ventricles.
	29th November	—	—	Digitalis stopped.
	2nd December	250.00	34.00	Ventricular extrasystoles.
1910	13th January ...	265.55	37.50	Ventricular arrhythmia.
	3rd February ...	280.03	35.55	Ventricles more rhythmic.
	10th February ...	252.99	31.92	Ventricles rhythmic
	24th March ...	258.46	32.43	Occasional ventricular extrasystole.
		246.77	32.70	
	28th April ...	254.23	36.20	Ventricles rhythmic.
	8th August ...	251.35	34.61	Ventricles rhythmic.

The patient experiences little inconvenience in spite of the frequent auricular action. This condition was at first transient, but the patient was unaware of either the onset or termination of the attacks. Since November, 1908, the auricular tachycardia has been constant, yet the patient's general health is now better than it was six years ago, and he is still able to earn a small livelihood. Although he does present a slight degree of cyanosis and has a little dyspnoea on exertion, it cannot be said that there is any other noteworthy clinical evidence of cardiac failure.

The pathological change in the heart is probably of syphilitic origin, for, although anti-syphilitic remedies have proved unavailing, we are indebted to Dr. F. E. Reynolds for the report that the patient's blood-serum yields a well-marked Wassermann reaction.

Graphic Records.

When the patient is in the recumbent posture, faint, rapid, fluttering, pulsatile movements can be seen in the jugular veins, and these movements can readily be recorded. In all the jugulo-carotid, apical and sphygmographic tracings reproduced in this paper, 1 indicates the commencement of the auricular wave; 2, the commencement of ventricular systole estimated from the start of the ventriculo-systolic rise in the cardiogram; 3, the appearance of the carotid elevation; 4, that of the pulse wave in the brachial artery; 5, the termination of ventricular systole as determined in the cardiogram; and 6, the opening of the tricuspid valve.

Tracings (Fig. 1) taken from *CASE I.* by means of the Knoll-Hering polygraph shew that during a period of ventricular diastole there are four or five positive waves in the jugulo-carotid tracing, with a number of small positive elevations in the cardiogram. In the jugulo-carotid tracing these waves represent the contractions of the right auricle, and the corresponding waves in the cardiogram are due to contractions of the left auricle. Both auricles, therefore, manifest the same fluttering movement. During the period of ventricular systole, the rhythmic appearance of the auricular waves in the jugulo-carotid tracing is apparently interrupted by the occurrence of the carotid and ventricular waves, and also by the fall in the curve

coincident with the opening of the tricuspid valve. But even at those times the auricular waves are seen to be superposed upon the jugulo-carotid curve, affording evidence that the right auricle continues to beat rhythmically at the same rapid rate during ventricular systole and diastole alike.

The evidence of the action of the left auricle during ventricular systole is not so clearly indicated in the tracings, yet as the systolic plateau of the cardiogram usually presents two, sometimes three, depressions, each corresponding in time to a positive auricular elevation in the jugulo-carotid curve, we think that these notches upon the cardiographic plateau may perhaps represent the pulling up of the ventricle upon the auricle each time the latter

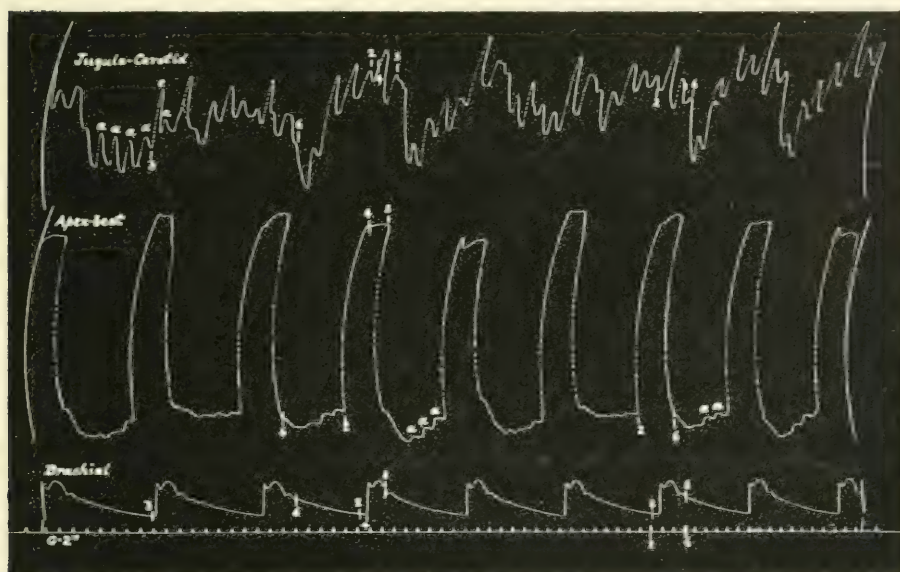


Fig. 1. *CASE I.* The jugulo-carotid and apical tracings present a series of rhythmic, positive waves, the rate of which is about 255 per minute. The ventricles contract rhythmically 32.2 times per minute.

contracts. According to Keith⁴³ the left auricle by its contraction draws the auricular base of the left ventricle upwards; and according to Wenckebach⁸⁰ this action of the auricle may cause a well-marked notch on the systolic plateau of the cardiogram when an auricular systole occurs synchronously with a ventricular systole in cases of cardiac arrhythmia.

In view of the evidence indicative of a lesion severing the auriculo-ventricular bundle in this patient's heart, it is not surprising that, although the auricles are in continual rapid flutter, the ventricles usually beat rhythmically about 32 to 35 times per minute. Occasionally there is a single ventricular extrasystole followed by a pause of the same duration as that following a beat when the ventricular rhythm is regular.

During a period of about three months in the autumn of 1909, however, the ventricular beats, on almost every occasion that the patient was examined, were more frequent (51 to 63 per minute), and less rhythmic. The ventricular rhythm never became wholly disorderly, but the beats occurred in groups of from two to sixteen more frequent beats, each group terminating with a pause of about the same duration as that after a systole when the ventricles were beating rhythmically and less frequently. This group-beating of the ventricles is described more fully and discussed elsewhere.²

The effect of Atropin on the Auricular Flutter.

The rate and rhythm of the auricular flutter were not influenced by atropin. In June, 1905, when the auricular rate was 273.03 per minute, the patient was given $\frac{1}{50}$ of a grain of atropin sulphate subcutaneously. Ten minutes later the auricular rate was 274.73 per minute. In October, 1909, the auricular rate was 268.1 before a similar dose of atropin was administered, 263.8 five minutes later, and 268.6 and 260.8 twenty and thirty-six minutes respectively after the drug had been given. The rate of contraction of a human auricle which is not fluttering, but which is beating rhythmically at an ordinary rate, is appreciably accelerated by $\frac{1}{50}$ grain of atropin sulphate. Thus in another case of auriculo-ventricular heart-block with an auricular rate of 87.43 and a ventricular rate of 44.11 per minute, the auricular rate increased to 96.77 nine minutes after the atropin had been given, and to 100.84 eleven minutes later. The corresponding ventricular rates were 44.11 and 43.47 per minute.

Electrocardiograms.

Although the tracings demonstrate that the auricles of this heart are in rapid, rhythmic flutter, even more convincing proof of the flutter is afforded by electrocardiograms.

Fig. 13 is an electrocardiogram derived from the two hands of *CASE I*. The deflection time of the galvanometer is here as in Fig. 11, 0.022 second. The summits *Q*, *R* and *T* are clearly visible, the last being inverted. The ventricles are beating at a rate of 32 per minute. The small rapid deflections are visible and, as in many pathological conditions, tremor being present, are more marked than in the electrocardiogram from the healthy subject. In addition to these it is evident that there is a series of fairly regular and slower deflections which are present during ventricular systole and diastole alike. These can be seen to be superposed upon the inverted summit *T*. It is not easy in Fig. 13 to determine the exact rhythm because of the simultaneous occurrence of the quick irregular deflections which complicate the curve.

Differentiation of slow and quick deflections. It has been shewn by Einthoven,¹⁵ in studying the electrical response obtained from the vagus nerve of the dog during natural respiration, that two series of deflections are present together, rapid variations produced by the heart beats and slow variations corresponding to the movements of the lungs. The galvanometer is not capable of shewing both series equally well at the same time. When the tension of the string is adjusted to render the quick with accuracy, the slow deflections are so small as to be scarcely perceptible. As the tension is reduced the sensitiveness of the instrument becomes proportionally greater, but at the same time the speed of deflection diminishes proportionately within certain limits. The quick deflections cannot then be shewn in their full value and are represented by small movements of the string, while the slow deflections which were previously less in amplitude than the quick, now much exceed the latter and their absolute value and rhythm can easily be studied.

Applying this method of differentiation in the present instance we diminish the tension of the string. In Fig. 14 is reproduced another electrocardiogram taken from the same patient as Fig. 13. Here one millivolt equals 25 mm.. Fig. 15 gives a control curve taken under the same conditions but with less magnification and greater rate of plate carrier. The deflection time of the string is seen to be 0.031 second. Comparing with the series published by Samojloff⁷² we find that this time is about twice as short as that at which the curve is observed by him to be distorted and the summit *S* invisible. Fig. 14 differs from Fig. 13 in that the slow deflections, previously masked to some extent, are brought clearly to light and it is evident that they present a fairly regular rhythm of about 270 per minute.

In Fig. 14 the ventricular deflections are irregular and occur at the rate of about 45 per minute. No constant relation holds between the two series. The waves which we are considering and which we may term *n* waves,^{*} may precede, succeed or occur simultaneously with any of the ventricular summits and are clearly seen superposed upon the slow summit *T*. The duration of each wave is about 0.11 second.

The origin of the deflections. The question arises to what are we to attribute these deflections? Excluding the action of skeletal muscles which has been already discussed, we have to consider the possibility of their origination by *venae cavae*, auricles or ventricles.

A deflection has been demonstrated by Einthoven¹⁶ in the electrocardiogram of the horse, and has been regarded by him as probably due to the action of the *venae cavae*. This consists of a small upwardly directed variation preceding that of the auricles by about 0.06 second and has been lettered *O*.

* The letter *f* has been used by Lewis⁴⁸ for waves on the electrocardiogram which he attributes to auricular fibrillation, in a paper which has appeared while this research was in progress. For the many interesting observations and the conclusions drawn by this author we refer to his publication.

Hering³¹ has recorded an electrocardiogram from a dog with thorax open, during vagus stimulation. Before the summit *P* and preceding it about 0.02 second is a small summit which the author regards either as an expression of the action of the sinus or as indicating that the auricles are not beating synchronously. No such deflection has so far as we know been demonstrated in the human electrocardiogram and we may therefore assume that the electrical change resulting from the action of the veins is as a rule too small in amount to affect the galvanometer. It is possible, however, that in some cases it may be visible. Fig. 16 gives the electrocardiogram of a patient in whom aortic insufficiency with hypertrophied left ventricle had been diagnosed clinically. The form of curve, however, is not typical of hypertrophied left ventricle. What we would draw attention to is the deflection preceding the auricular summit by about 0.08 second. This deflection, where best marked, consists of an upward summit and lasts for about 0.057 second. This agrees fairly well with the duration of the deflection *O* of the horse's electrocardiogram and it is probable that it is to be attributed to the same cause.

From the fact that the ventricular variation in the curve of Fig. 13 and 14 is typical in form we have no reason to believe that the *n* waves are derived from the ventricles and it is probable that they are auricular in origin.

Very rapid rates of auricular beat have been observed. In the case already mentioned recorded by Hertz and Goodhart³² the auricles beat at the rate of 234 per minute. The jugular tracings shewed an exceedingly rapid but absolutely regular pulsation which had no relation to the ventricular contractions as indicated by the records of the apex-beat. The authors were of opinion that the jugular curve represented "genuine auricular" and not "so-called fibrillary" contractions.

The auricular deflection in the electrocardiogram of a healthy human subject has a value of 100 to 200 microvolts. It varies much in pathological conditions. Einthoven¹¹ has recorded a case of mitral stenosis where this deflection reached a value of 500 microvolts. The *n* waves in Fig. 14 have a value of about 60 microvolts. The duration of the auricular deflection in the healthy heart is about 0.1 second. It has been shewn that where there is mitral stenosis the auricular deflection may be lengthened.¹⁰

Comparing the waves in the present curve with the normal auricular deflection we find that they agree with it fairly well in duration, but are smaller and much more rapid.

Are we to look upon the waves as evidence that the auricles are in the condition known as "fibrillar contraction"? The term "fibrillar contraction" as applied to what results in the ventricle experimentally after the application of various forms of stimuli means the substitution for the co-ordinated beat of a state of irregular arrhythmic contraction—an inco-ordinated quivering movement of the cardiac musculature which is inefficient

in propelling the blood.* The waves which we are considering do not give evidence of inco-ordinate movement but rather of rapid shallow regular contractions.

The condition present in the auricles of our case does not therefore appear to agree with that known as fibrillar contraction of the ventricle. The term fibrillar contraction has, however, also been applied to the condition following faradisation of the auricles and there is some evidence that the phenomena are not identical in the two cases. MacWilliam⁶² states that, "the application of the current sets the auricles into a rapid flutter, the rapidity of which largely depends upon the excitability of the auricular tissue and the strength of current employed. The movements are regular; they seem to consist of a series of contractions originating in the stimulated area and thence spreading over the rest of the tissue. The movement does not shew any distinct sign of inco-ordination; it looks like a rapid series of contraction waves passing over the auricular walls. The difference between this appearance and that seen in the ventricles probably depends on the simpler structure and arrangements obtaining in the auricles." Contractions such as this author describes might very well give rise to the electrical changes which we are studying, and we have to consider how far this author's observations are borne out by the electrical changes obtained after faradisation of the auricles and ventricles respectively. Curves have been recorded by Kahn⁴¹ from dogs a few seconds after the ventricles had been thrown into fibrillar contraction by faradisation. Large deflections which are entirely irregular are produced in consequence.

Records of the action of the auricles and ventricles of the dog after faradisation. In Fig. 17 we give a curve obtained from a dog, anaesthetised by chloroform, by the derivation from right anterior and left posterior limbs (derivation II) after strong faradisation of the ventricles. The deflections give no evidence of co-ordinate movements, nor regular rhythm, but represent summation and interference of many irregular variations.

Fig. 18 has been obtained in the following way. The ventricles of an anaesthetised dog were faradised and fibrillar contraction resulted. When this had to all appearance completely ceased and the ventricles were quiescent, the auricles were still observed to be beating in a co-ordinate manner. The right auricle was then faradised and the electrocardiogram recorded from right anterior and left posterior limbs. The curve does not give evidence of an entirely regular rhythm, but the irregularity appears to be less than in the case of the ventricles. Many of the deflections seem to give evidence of a co-ordinate contraction and some consist of an upward deflection followed after a pause by a downward deflection. This is similar to what is observed when derivation II is employed with *CASE I*, of our series.

We prefer to term the condition in this patient auricular "flutter" rather than fibrillation.

* For the characters of fibrillar contractions of the ventricle see Kronecker and Schmey.⁴⁶

From Fig. 13 and 14 it is evident that the ventricles are not beating regularly in *CASE I*. From other records we find that at the time these electrocardiograms were taken the ventricular beats were occurring in groups containing 2 to 16 quicker beats, each group being terminated by a ventricular period lasting about nine-fifths of a second. Fig. 14 shews one of these premature beats.

Interpretation of the ventricular summits of the electrocardiogram. The downward summit *Q* is rather more marked than in the healthy heart. This summit is known to initiate the ventricular deflection. Its downward direction is held to indicate that the apex of the heart or the left as against the right ventricle first becomes active in ventricular systole.

According to Einthoven¹² the course taken by the wave of contraction which passes through the heart is neither simply from base to apex nor the reverse. The auriculo-ventricular bundle through which the excitation passes from auricles to ventricles conducts the stimulus presumably to the wall of the ventricle at many different points simultaneously. The systole of the ventricle thus begins at almost the same time in different parts and the expression of this is seen in the three summits *Q*, *R*, and *S* of the electrocardiogram. A somewhat similar explanation is given by Nicolai,⁶⁴ who considers that after the horizontal part of the curve, during which the excitation is traversing the auriculo-ventricular bundle, the basal part of the papillary system becomes active and that this is evidenced by the steep summit *R* of the electrocardiogram, which the author, varying the usual nomenclature, terms summit *J*.

Eppinger and Rothberger¹⁸ consider that the ventricular curve gives evidence of the action of two opposed forces associated with the contraction of, (1) the longitudinal muscle fibres of the ventricular wall, and (2) the circular fibres or "Treibwerk." They attribute summit *R*, at least in its ascending part, to the action of the longitudinal fibres together with the papillary muscles, and regard the descending part of *R* and the pause following it as due to the circular fibres. Kahn⁴² has shewn experimentally that *R* is completely over before the musculature of the ventricular wall begins to contract and that the intra-ventricular pressure begins to rise and the first heart sound occurs after this deflection has run its course. This observer regards *R* as pertaining to the activity of the papillary system and independent of the contraction of circular or longitudinal fibres.

No explanation of the summit *Q* is offered by Nicolai who regards *R* as initiating the series of deflections which are derived from the ventricles. The summit *Q* is however, according to Einthoven, a quite typical constituent of the curve from the healthy heart although usually not so marked as in the present case.

Fig. 19 represents the electrocardiogram from *CASE I* when the current is derived from the right hand and left foot (derivation II). It differs from Fig. 14 in that the first of the ventricular series of summits is upwardly

directed. This is followed immediately by a downward deflection and the summit T_H is upward.

Fig. 20 represents the curve derived from left hand and left foot (derivation III). The direction of the ventricular summits is the same as in Fig. 19. The beginning of the ventricular series consists of an upward followed by a downward deflection. The n waves are at the rate of 272 per minute.

When we compare the form of the n waves obtained by derivations II and III with that yielded by derivation I we observe a difference. By derivation I each wave consists of a simple rise and fall of the curve, by derivations II and III on the other hand the wave is clearly diphasic, being composed of a deflection upwards and a deflection downwards separated by an interval during which the shadow of the string traces a horizontal line. The upward deflection is less acute than the downward. The duration of the former is about 0.1 second, that of the latter 0.059 second.

From derivation I we obtain information chiefly with regard to the electrical condition of one ventricle as against the other, and to a less extent of base as opposed to apex. We have seen from Fig. 14 that the results obtained in this way indicate that the stimulus has reached the ventricles first at a point near the apex or the left ventricle. Taking this in conjunction with the results obtained by the other methods we may conclude that it is to the base of the left ventricle especially that the stimulus is first conducted.

In Fig. 14 the first of the two premature beats lettered a differs in form from the other ventricular deflections. The summit Q is absent. R is slower than usual, its rise and fall occupying a considerably longer time. Variations among the ventricular deflections are to be expected since the n waves whose rhythm is different and independent are summed algebraically with them, but the deviation here is greater than can be explained in this way. Further T is conspicuously deeper and we must regard a as an atypical systole. Such atypical systoles are of varying appearance. The example here figured is very similar to some figured by Einthoven.^{11, 13} The absence of Q would denote that the excitation has here commenced in the ventricles at a point nearer the right ventricle than in the other contractions. This is the only instance of the absence of Q by derivation I which we have observed in our series from this patient. The interval separating the beginning of R from the beginning of the previous R (0.63 second) is the shortest we have recorded from this patient.

With regard to the summit T , we have to consider two theories of its causation which have been advanced. According to Einthoven the horizontal part of the curve between the summits S and T represents a state of contraction in which the musculature of both ventricles participates equally and the presence of summit T which is upwardly directed in the case of the

healthy heart is due to the fact that the right ventricle remains longer in contraction than does the left.

Another explanation has been put forward by Nicolai^{64,65} who considers that the base of the ventricles becomes active a second time in systole and that T is an evidence that the excitation has ascended to the base. This view finds support in experimental work by Gotch²³ who placed electrodes upon different parts of the exposed heart of the rabbit, and studied the electrical variations by means of the capillary electrometer. This observer finds that when contacts are made at the base of the ventricle equidistant from the groove, one far away from the aorta and the other near the aorta, activity commences first under the contact distant from aorta. This is succeeded by a period of equipotential and lastly there develops activity near the aorta.

With regard to the first of the two views we would point out that it is not necessary to assume, in order that the usual upward T should appear when contact is made from the two hands, that the left ventricle ceases to contract before the right. If the preceding horizontal part of the curve is due to a compensation of the action currents of the two ventricles then predominance of activity of one ventricle towards the end of systole would be sufficient to determine a rise or fall of the curve according as right or left ventricle predominates. So far as we know there is no evidence apart from the electrocardiogram that the right ventricle remains in contraction longer than the left.

The second hypothesis affords an explanation of the upward deflection T , its causation being probably related to the return of the contraction wave along the ventricular wall to the parts from which the aorta and pulmonary artery spring and possibly to the walls of these vessels, and Gotch²³ points out that "if so, then as this part of the cardiac activity is of great importance from the point of view of the circulation, the degree to which it is appreciable in human electrocardiograms is a significant indication both of the efficient working of the heart and of the intra-cardiac pressure."

We know that T may be diminished or absent in various pathological conditions such as degeneration and insufficiency of the heart and a horizontal line in place of this summit might be taken to indicate failure of the second basal activity, but it is less easy on this hypothesis to account for inversion of the summit, whereas in accordance with the other view impairment of activity of the right ventricle might lead to disturbance of the equilibrium in favour of the left ventricle.

The fact that the summit T is negative in Fig. 14 where the current is led from the hands might be held to imply that the activity of the left ventricle towards the end of systole predominates over that of the right, while the upward direction of the summit in Fig. 20 would indicate that at the same period basal activity predominates over apical.

AURICULAR FIBRILLATION IN THE HUMAN HEART.

Resumé of the literature on the action of the auricles in perpetual arrhythmia of the heart.

In the earlier part of this paper we have discussed fully a case where a series of regular auricular waves is presented in the electrocardiogram and by mechanical registration ; and we have brought forward the evidence which leads us to conclude that the condition is one of flutter rather than fibrillation. We now proceed to discuss auricular fibrillation.

Perpetual arrhythmia—the “nodal rhythm” of Mackenzie—is a distinct form of cardiac arrhythmia. Mackenzie shewed that it is associated with a ventricular venous pulse and that the auricles no longer contract at their proper time in the cardiac cycle. It has been suggested that perpetual arrhythmia of the ventricles is associated with:—

1. *Paralysis, or asthenia, of the auricles* Mackenzie,⁵⁵ Gerhardt,²⁰ Lingbeek and Vrijdag,⁵⁰ Hewlett,³³ Theopold,⁷⁷ Magnus Alsleben,⁶³ Hay,²⁵ Joachim,⁴⁰ Rautenberg,⁶⁹ Hering,²⁹ Samojloff and Steskinsky,⁷³ and Strubell.⁷⁶ Hoffmann³⁶ found that the auricular deflection *P*, was sometimes, but not constantly, absent.

2. *Contraction of the Auricles simultaneously with the Ventricles*, owing to (a) increased excitability of the auriculo-ventricular node—the “nodal rhythm” of Mackenzie (57, 59). The problem has also been investigated by Lohmann,⁵¹ Kraus and Nicolai,⁴⁵ and Lewis,⁴⁷ ; or (b) a sino-auricular block comparable to the first Stannius ligature. This theory propounded by Wenckebach,⁷⁹ found support in the experimental researches of Engelmann,¹⁷ Lohmann,⁵² Hering,³¹ and Cushny,³ in the clinical observations of Mackenzie,⁶⁰ and in the pathological studies of Radasewsky,⁶⁸ Dehio,⁵ Schönberg,⁷⁵ Koch,⁴⁴ and Hedinger.²⁷ Jäger,³⁷ however, found that the rhythm of the heart remained unchanged after destruction of the sino-auricular node.

3. *Auricular Fibrillation*. Since Ludwig and Hoffa,⁵⁴ recorded their classical observations it has been known that the application of a faradic current to the ventricles may induce fibrillar contraction of the ventricular musculature. Vulpian,⁷⁸ MacWilliam,⁶² Jellinek,³⁹ and Winterberg,^{81, 82} shewed that when the ventricles are in fibrillar contraction the auricles usually beat in a co-ordinate manner. The researches of MacWilliam,⁶² Philips,⁶⁶ Fredericq¹⁹ and Winterberg,⁸² demonstrated that when the auricles are in fibrillation the ventricles do not usually pass into fibrillation but that their rhythm becomes wholly disorderly. The suggestion that perpetual arrhythmia of the human ventricles might be associated with auricular fibrillation was brought forward by Cushny and Edmunds.⁴ Evidence in favour of

this theory may be found in the graphic records published by Mackenzie,^{56, 61} Schmoll,⁷⁴ Hewlett,³⁴ Lewis,⁴⁸ and Hay,²⁶ and in one of the electrocardiograms recorded by Kraus and Nicolai.⁴⁵ The question of auricular fibrillation has also been discussed by Hering,³⁰ Hewlett,³³ and Hirschfelder.³⁵ The important researches of Rothberger and Winterberg,⁷¹ and of Lewis⁴⁸ shewed the essential similarity of the electrocardiographic records in perpetual arrhythmia of the human heart and in experimental auricular fibrillation.

Clinical features, graphic records and electrocardiograms of cases of perpetual arrhythmia of the ventricles.

In ten cases of perpetual arrhythmia we have studied the action of the auricles by means both of electrocardiograms and mechanical records.

CASE II, Greengrocer, aged twenty, under the care of Dr. G. A. Gibson, in the Royal Infirmary. The patient had suffered from whooping cough at the age of three, and from scarlet fever at the age of ten, but he had never suffered from acute rheumatism. For four months he had complained of "fluttering of the heart" which he had first experienced while walking down a hill towards his work. He had no pain or dropsy, and very little breathlessness. The apex-beat was in the fifth left intercostal space, in the mammary line; a well marked systolic thrill accompanied by a loud blowing murmur were perceptible at the apex of the heart. The arterial pulse was continually irregular.

In Fig. 2 the jugulo-carotid tracing shews slow respiratory movements, and also elevations representing *c*, *v*, and *h* waves. In addition there is a series of small and fairly rhythmic waves indicated by the letters *a*. These *a* waves, which are most evident during the longer diastolic phases, occur at a rate of about 400 per minute. They are to be regarded as evidence of auricular contractions.

Fig. 21 gives the electrocardiogram from *CASE II* by derivation III. The summit *R* is upwardly directed in the curves obtained by the three methods of derivation from this patient. *T* consists of a downward deflection succeeded, most markedly when derivation III is employed, by an upward deflection. There are well marked waves on the curve occurring at a rate of about 504 per minute. These waves are not continuous but noticeably intermittent. In Fig. 21 at *a* is seen a period in which they are absent.

CASE III, mason, aged sixty-seven, under the care of Dr. Alexander Bruce in the Royal Infirmary. The patient had never suffered from acute rheumatism or syphilis, and had always enjoyed good health until December, 1909, when he suffered from rheumatic pains in the legs. Three weeks later he began to complain of breathlessness, palpitation and precordial pain, for which he sought admission to hospital. When the records in Fig. 24, 3, 22 and 23 were taken, there was no cyanosis or dropsy; the chest was emphysematous; the apex-beat was in the sixth intercostal space four and

a half inches to the left of the mid-sternal line. No cardiac murmurs were audible, but both sounds were faint, and the second was slightly reduplicated.

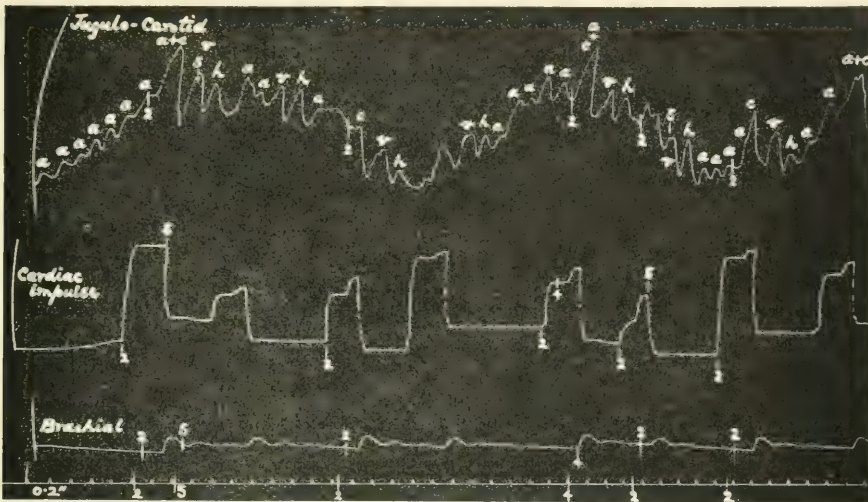


Fig. 2. *CASE II.* Perpetual arrhythmia of the ventricles. During ventricular diastole there is a series of positive waves, *a*, in the jugulo-carotid tracing.

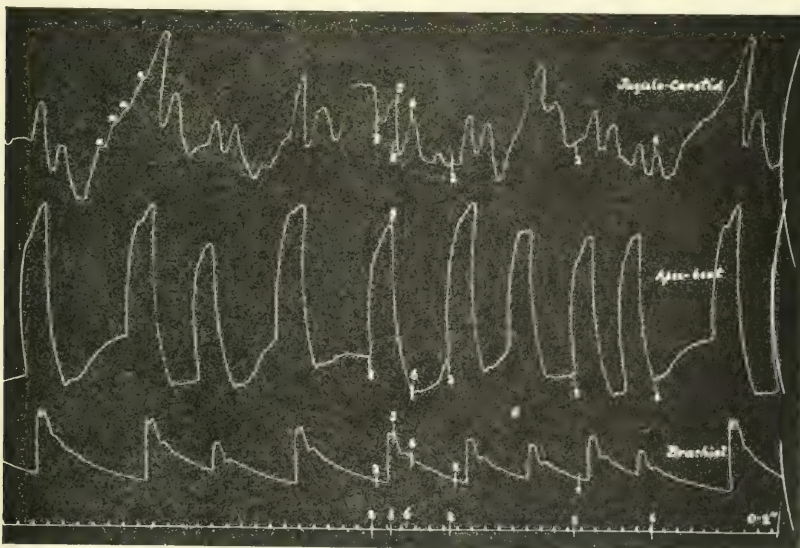


Fig. 3. *CASE III.* Perpetual arrhythmia of the ventricles. The ventricular venous pulse presents little evidence of auricular action.

The radial arteries were thick ; the pulse was continually irregular (Fig. 3) ; and the systolic blood pressure, estimated by Martin's modification of the

Riva-Rocci sphygmomanometer was equal to 190 mm. Hg.. The urine contained a trace of albumin.

The jugulo-carotid tracing in Fig. 3 presents a ventricular venous pulse. The tracing reveals little evidence of auricular contractions, unless the small waves, *a*, during the longer ventriculo-diastolic phases can be regarded as expressing a feeble auricular action.

Figs. 22, 23 and 24 are recorded by derivations I II and III, from *CASE III*. By derivation I, *R* is upward and *T* consists of a downward followed by an upward deflection. By derivations II and III the ventricular variation is initiated by an upward followed by a downward deflection and *T* is scarcely perceptible. Each of the figures presents atypical systoles. In Fig. 22 these are of two distinct forms. The beats lettered *a* present a form consisting of downward *Q* and *S* with upward *R*. It differs from the normal beat in this patient by the presence of *S* and by the great height of *R*. The second form of atypical systole is seen at *b*. Here the ventricular variation is initiated by an upward followed by a downward deflection and *T* is a lofty upward summit. In Figs. 23 and 24 the atypical systoles marked *b* are closely similar to the second form in Fig. 22. They differ from the normal beats as rendered by derivations II and III in presenting a high upward summit *T*. The auricular waves in this case occur at a rate of about 435 per minute.

CASE IV. Cabinetmaker, aged twenty-seven, had suffered from empyema when three years of age, but had never been affected with acute rheumatism or syphilis. At the age of twenty-five, he began to feel breathless on exertion; a year later he suffered from a hemiplegia. When admitted to Dr. John Cowan's wards in the Glasgow Royal Infirmary he was found to present the characteristic signs of mediastino-pericarditis:—(Systolic retraction over the whole precordia, fixation of the apex-beat, Broadbent's sign, *pulsus paradoxus*, etc.). No cardiac murmur was audible, but the systolic retraction of the apex-beat was accompanied by one sound, while two sounds accompanied the strong diastolic impulse. The arterial pulse was continually irregular, and Dr. Cowan kindly arranged for the patient's admission to Dr. Gibson's ward in the Edinburgh Royal Infirmary.

In Fig. 4 the arterial pulse is continually irregular. The cardiogram is inverted. In the jugulo-carotid tracing, the commencement of the sharp fall *y* is almost synchronous with the start of the ventriculo-diastolic rise in the cardiogram. This is marked by the numeral 6 in the tracing, and indicates the moment at which the tricuspid valve opens. The depression *y* is followed by an equally sudden positive wave, which we regard as an *h* wave. Subsequent to this there is a plateau with small positive elevations, *a*, representing auricular contractions, superposed upon it; and a further rise coincident with the start of ventricular systole as determined in the cardio-

gram and about 0.12 second before the appearance of the pulse wave in the brachial artery. The plateau of the jugulo-carotid curve ends when the tricuspid valve again opens.

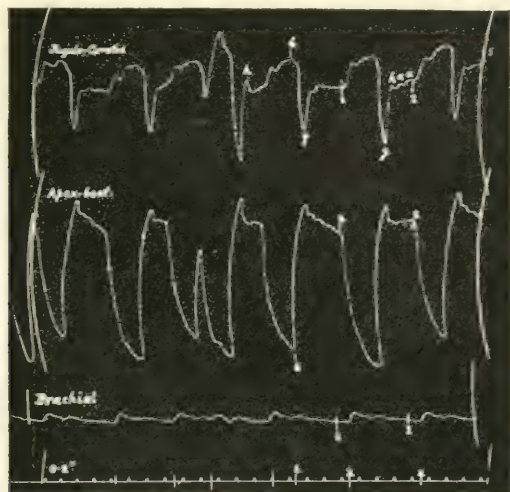


Fig. 4. *CASE IV*. Perpetual arrhythmia of the ventricles. The cardiogram is inverted. In the jugulo-carotid tracing there is a depression, *g*, commencing at 6 when the tricuspid valve opens. This is followed by an *h* wave, and then by a plateau during the remainder of ventricular diastole and during the succeeding ventricular systole which commences at 2. Upon this plateau there are small positive waves, *a*, probably representing auricular fibrillation.

Fig. 25 is from *CASE IV* by derivation II. The ventricular deflections are of the usual form except that *T* is downward. The waves are at a rate of about 462 per minute.

CASE V Rubber-worker, aged twenty-one, under the care of Professor Greenfield in the Royal Infirmary. The patient had suffered from acute rheumatism and pericarditis at the age of sixteen. Thereafter he had always been somewhat breathless and had complained of precordial pain and palpitation. There was never any dropsy. The apex-beat was in the fifth left intercostal space, 8 cm. from the midsternal line; the percussion borders of the heart at the level of the fourth intercostal space were 4 cm. and 11 cm. to the right and left of the mid-sternal line. A short, somewhat rough, presystolic murmur was distinctly audible over the apex-beat; the first and second sounds were closed, but the latter was followed by a short, soft, diastolic murmur of mitral origin. The arterial pulse was continually irregular. In the jugulo-carotid tracing of Fig. 5 the venous pulse is of the ventricular form, and during the longer ventriculo-diastolic phases a series of small positive waves, *a*, occurs, which we regard as evidence of auricular contractions.

Fig. 26 gives the electrocardiogram from *CASE V*, by derivation III. By each derivation summit *T* is upward. By derivation I the ventricular variation is initiated by an upward followed by a downward deflection and by derivations II and III there is an upward *R*. The waves which occur on this electrocardiogram are at the rate of 390 per minute.

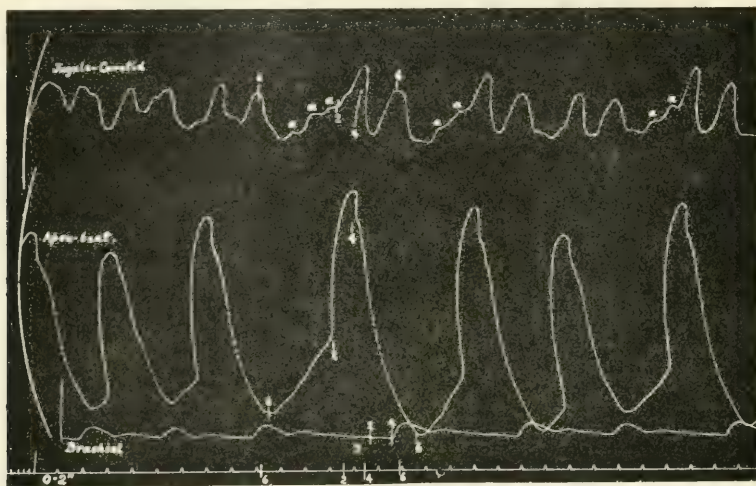


Fig. 5. *CASE V*. Perpetual arrhythmia of the ventricles. During the longer ventricular diastoles the jugulo-carotid tracing presents small positive waves, *a*.

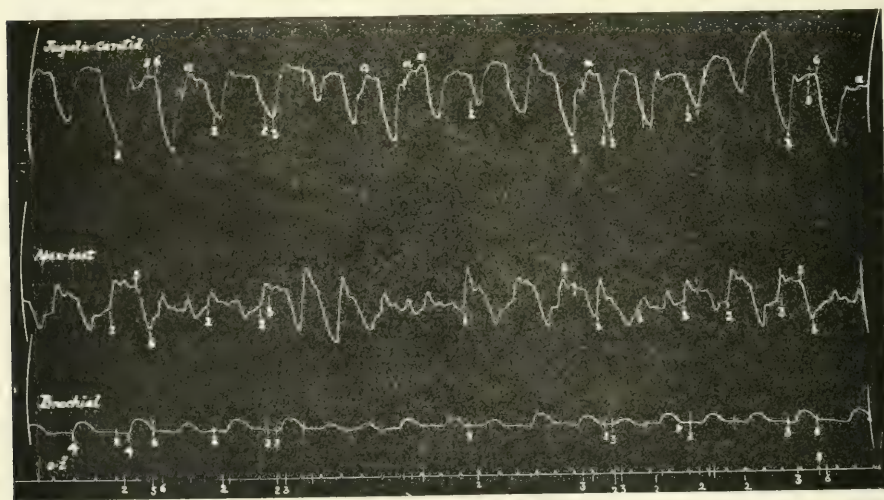


Fig. 6. *CASE VI*. Perpetual arrhythmia of the ventricles. Superposed upon the ventricular venous pulse are small positive waves, which probably represent fibrillar contractions of the auricle.

CASE VI. Painter, aged sixty-six, had suffered from acute rheumatism at the age of fifty-five, and had been complaining of cardiac symptoms for

eight months before the records in Figs. 6 and 27 were obtained. The feet and legs were oedematous. The first sound at the mitral area was rough, but no definite presystolic murmur was audible. The arterial pulse was continually irregular, and there was a ventricular venous pulse in the jugular veins (Fig. 6). Small positive waves, *a*, are present upon the systolic plateau of the jugulo-carotid tracing. Their rate is about 600 per minute. The arterial pulse remained continually irregular until the patient died several months later of carcinoma of the stomach and liver.

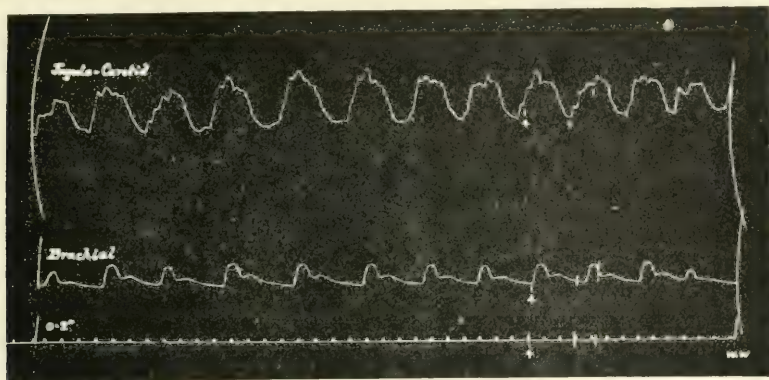


Fig. 7. *CASE VIII.* Perpetual arrhythmia of the ventricles. The series of small positive waves superposed upon the ventricular venous pulse tracing probably represents auricular fibrillation.

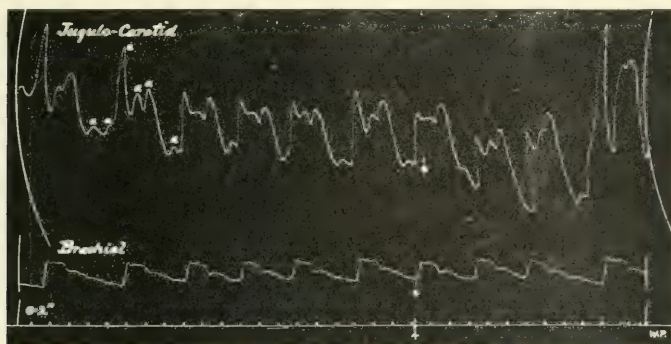


Fig. 8. *CASE IX.* Perpetual arrhythmia of the ventricles. The series of positive waves superposed upon the ventricular venous pulse curves probably represent auricular fibrillation.

Fig. 27 is the electrocardiogram by derivation I of *CASE VI*. *R* and *T* are upward, and irregular waves are to be observed.

CASE VII. Widow, aged seventy-two, had never suffered from acute rheumatism, but had complained of chronic bronchitis for several years. The left border of the heart was one inch to the left of the mammillary line; no presystolic murmur was audible; the radial arteries were thick; the

arterial pulse was continually irregular; the feet and legs were markedly oedematous. The jugular veins presented no visible or recordable pulsation. The patient died two months after the record in Fig. 29 was obtained.

Fig. 28 is recorded from *CASE VII* by derivation I. *R* and *T* are upward, and irregular waves can be seen at a rate of about 516 per minute.

CASE VIII. Tinsmith, aged sixty, affected with chronic Bright's disease, came under our observation in September, 1909, when the electrocardiogram in Fig. 29 was obtained. The patient had never suffered from acute rheumatism, but had manifested cardiac symptoms for eleven years. Although troubled by dyspnoea on exertion there was no cyanosis or dropsy, and he was able to follow his trade. The left border of the heart was four and a half inches to the left of the mid-sternal line; no valvular murmurs were audible; the radial arteries were not palpably thickened; the arterial pulse was continually irregular, and the jugular pulse was of the ventricular form (Fig. 7). The series of small waves upon the line of ascent and upon the plateau of the jugulo-carotid tracing we regard as evidence of rapid, feeble contractions of the auricular musculature at the rate of about 720 per minute. The patient was under observation for eight months, and was regularly at his work all that time, although the rhythm of the pulse was wholly disorderly.

Fig. 29 is recorded from *CASE VIII* by derivation I. *R* is upward, *T* consists of a downward followed by an upward deflection and small irregularities are visible.

CASE IX. Labourer, aged sixty-five, had never suffered from acute rheumatism or syphilis. The lungs were emphysematous, the patient was troubled with dyspnoea on exertion, and the feet and legs had been swollen for some months. Under the influence of digitalis the patient's condition improved considerably, and in August, 1909, when the record in Fig. 30 was obtained there was no valvular murmur audible, no cyanosis, dropsy or albuminuria. The radial arteries were thick, and the pulse was continually irregular (Fig. 8). The systolic blood pressure estimated by Martin's modification of the Riva-Rocci sphygmomanometer was equal to 165 mm. Hg.. The jugular pulse was of the ventricular form (Fig. 8), and the ventricular rhythm was wholly disorderly. In Fig. 8 there is a series of small waves, *a*, both upon the systolic plateaux of the jugulo-carotid tracing and during the periods of ventricular diastole.

Fig. 30 represents the electrocardiogram of *CASE IX* by derivation I. The patient shewed considerable muscular tremor which is apparent on the curve. Fig. 31 gives the curve by the same derivation with increased sensitiveness of the instrument. *R* and *T* are upward. In this figure two atypical systoles are shewn. In the first of these marked *a*, where the period separating *R* from the preceding *R* is 0.49 second, the summit *Q* is absent or inconspicuous, *R* is followed by a deep *S*, and *T* is increased. In the second, marked *b* where the period between *R* and *R* is 0.46 second, *Q* is increased *S* present and *T* increased.

In both figures there are seen rather irregular deflections which are especially evident in the longer diastolic periods. These occur at a rate of from 480 to 500 per minute.

CASE X. A woman, aged sixty-one, under the care of Dr. Lovell Gulland in the Chalmers Hospital. The patient had suffered from acute rheumatism three times, and had been troubled with her heart for ten years. She had been breathless and dropsical for two years before admission to hospital, and had recently suffered from pericarditis and pleurisy. When the electrocardiograms (see Fig. 32) were obtained, the swelling of the feet, the ascites, and the crepitation at the bases of the lungs had disappeared under the influence of rest and digitalis. The apex-beat was in the fifth intercostal space, five inches to the left of the mid-sternal line. The only valvular murmur audible was a systolic murmur of mitral origin. No venous pulsation was visible in the neck. The arterial pulse was continually irregular, with a rate of about 104 per minute.

Fig. 32 gives the electrocardiogram from *CASE X* by derivation II. No atypical systoles are shewn. Summit *R* is upward in this patient by derivation I while *T* consists of a downward followed by an upward deflection. By derivation II a deep *S* is present and *T* is upward, and by derivation III the ventricular variation consists of upward followed by downward deflection and upward *T*. Waves are seen to occur at a rapid rate which it is difficult to measure with accuracy.

CASE XI. Clerk, aged twenty-four, under the care of Dr. G. A. Gibson in the Royal Infirmary. The patient had an initial and severe attack of acute rheumatism at the age of eighteen, and several subsequent attacks, and had been breathless ever since the first attack. Three months before his admission to hospital he was seized with sudden palpitation and a "cramping sensation about the heart;" but there has been no dropsy, and but little dyspnoea. When the patient lay on his back, the apex-beat was in the seventh intercostal space, five and three-quarter inches to the left of the mid-sternal line. The right border of the heart was three and a quarter inches to the right of the mid-sternal line. The position of the apex-beat varied at least three inches according as the patient lay on his left or right side. There was well marked systolic retraction of the lower ribs and intercostal spaces on the left side posteriorly, the retraction being most pronounced at the tenth intercostal space. A loud mitral systolic murmur, an accentuated second sound, and a soft mitral diastolic murmur were audible. The rate of the cardiac impulse and of the arterial pulse was usually about 40 to 45 per minute, and their rhythm was wholly irregular (Fig. 9). The jugulo-carotid tracing in Fig. 9 presents a ventricular venous pulse, with a series of rapid, somewhat irregular waves, *a*, superposed upon it during the periods of ventricular diastole.

Fig. 33 gives the electrocardiogram from *CASE XI* by derivation II. Summit *R* is upward, and *T* downward, by derivations I and II. By derivation III the initial ventricular complex consists of an upward followed by a deep downward deflection, and summit *T* is upward. Auricular waves are present in each of the curves. They occur at a rate of about 522 per minute.

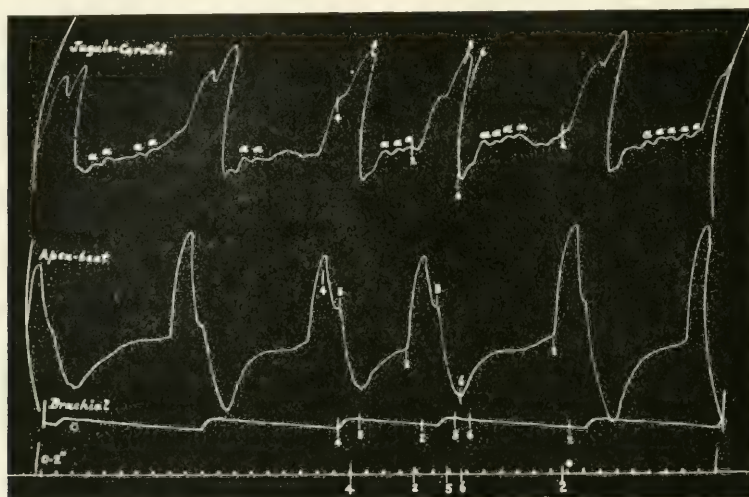


Fig. 9. *CASE XI*. Perpetual arrhythmia of the ventricles. During ventricular diastole a series of small, irregular, positive waves due to auricular fibrillation are observed in the ventricular venous pulse.

In the jugulo-carotid tracings obtained from our cases of perpetual arrhythmia, we find that, although the venous pulse is of the ventricular form, a series of smaller, positive, waves is often superposed upon the curve. As was demonstrated by Mackenzie⁵⁶ this series of small waves is usually most evident during a long ventriculo-diastolic period (see Fig. 2, 5 and 9), and therefore is more readily observed in cases of perpetual arrhythmia with an infrequent, rather than a frequent, rate of ventricular contraction. The small positive waves may also occur in the jugulo-carotid tracing during the period of ventricular systole (see Fig. 6, 7, 8). These small waves are seldom quite rhythmic, yet their rhythm is usually fairly regular. In most instances it is difficult to estimate their frequency, but in *CASE II* (Fig. 2), where they are well marked they occur at a rate of about 400 per minute. In *CASE VI* (Fig. 6), the rate appears to be about 600 per minute, and in *CASE VIII* (Fig. 7), about 720 per minute. The amplitude of the waves varies considerably in different cases. In *CASES III* and *IV* (Fig. 3 and 4), the waves are small; in *CASES V, VI* and *VIII* (Fig. 5, 6 and 7), the waves are of greater amplitude. They are largest in *CASE II* (Fig. 2),

approaching more closely to those produced by the auricular flutter in *CASE I* than do any of the remaining cases.

Comparing the *a* waves in the jugulo-carotid tracings from our case of auricular flutter (*CASE I*, Fig. 1) with the *a* waves in our cases of perpetual arrhythmia of the ventricles, we find that the latter are of lesser amplitude, of greater frequency, and of somewhat less regular rhythm. The resemblance of the waves representing auricular flutter in *CASE I* to the *a* waves in perpetual arrhythmia led us to conclude that the latter were probably not artefacts, but were the graphic evidence of auricular contractions. In *CASE I*, it is probable that the auricular flutter never had any direct influence upon the ventricles, because there was a lesion severing the auriculo-ventricular bundle. In none of the cases of perpetual arrhythmia which we record, however, was there any clinical evidence indicative of a lesion severing the bundle: and in all these cases with a ventricular rhythm which was wholly disorderly the ventricles were apparently subject to a sino-auricular influence. The conditions were thus comparable to the disorderly ventricular rhythm associated with auricular fibrillation in Fredericq's¹⁹ experiments on hearts with the auriculo-ventricular bundle intact. In *CASE XI* of our series it is probable that the infrequent ventricular rate was due to depression of conductivity in the auriculo-ventricular bundle, and that this depression was partly the result of digitalis.

The final proof that the auricles in these cases of perpetual arrhythmia were neither paralysed nor were contracting at the same rate as, and synchronously with, the ventricles was afforded by the electrocardiographic records.

The cases above described agree in the fact that the summit *P* indicating normal activity of the auricles is absent. They also agree in presenting irregular oscillations or waves whose rates range in the several cases from 390 to 522 per minute. These waves are not continuous in the curves, some of the periods being entirely free from them. There is no uniformity in the ventricular variations, many different forms being shewn.

Several of the curves contain atypical systoles and these may be rendered in different forms in the same patient and by the same mode of derivation. As a rule they are preceded by shortened pauses, but this is not invariably the case. In Fig. 23 where the interval between two normal ventricular systoles is 0.7 second, a pause of about 1 second separates the second of these from an atypical systole.

The appearance presented by these electrocardiograms is very similar to that from a case of mitral incompetence figured by Einthoven,⁸ and to those recorded by Lewis.⁴⁸ The waves are probably of the same nature as those described by Lewis and attributed to fibrillation of the auricles.

Experiments on animals and comparison with perpetual arrhythmia in the human heart.

The experiments were carried out upon dogs. The animals were anaesthetised with chloroform and artificial respiration was employed. The thorax was opened and the pericardium slit. Two electrodes which consisted of small barbed fly hooks attached to insulated wires were inserted in the right auricle and the thorax reclosed. A photograph of the electrical variation was taken and then strong faradic stimulation was applied to the right auricle. A second photograph was taken immediately after the cessation of stimulation.

Fig. 34 represents the electrocardiogram of a dog by derivation II after stimulation of the auricles. The control curve taken before stimulation was typical. The heart was then beating regularly at a rate of 100 per minute; *P*, *R*, and *T* were present. The summit *T* consisted of a slow and a rapid upward deflection separated by a downward deflection. The curve presented no waves in addition to the usual summits. Fig. 34 shews that the ventricle after auricular stimulation has lost its regularity. The ventricular variation is little changed, but in place of the auricular variation there is a series of irregular deflections occurring at a rate of about 612 per minute. The appearance presented after auricular stimulation therefore closely resembles that observed in cases of perpetual arrhythmia and we are able to confirm Lewis'⁴⁸ observations on this point.

The electrocardiograms from cases of perpetual arrhythmia in the human heart and from animals whose auricles have been submitted to faradisation agree with those we have described from *CASE I* in presenting a series of small deflections in place of the usual summit *P*. They differ from them, however, in the irregularity of the waves and in their greater rate. Further, they do not shew by any derivation the diphasic appearance which is characteristic of the curves recorded from *CASE I* by derivations II and III. We cannot therefore regard the two sets of waves as identical; and if those in perpetual arrhythmia are to be attributed to fibrillation of the auricles as seems probable from the evidence at present before us, we prefer to use the term "flutter" to designate those from *CASE I*.

We have to acknowledge to Professor Schafer our thanks for encouragement, advice, and assistance in the work, especially in connection with the experiments on animals. In conclusion, we desire to express our indebtedness to Professor Greenfield, Dr. G. A. Gibson, Dr. Alexander Bruce, and Dr. Lovell Gulland for permission to examine the cases in their wards, and to their Resident Physicians, Drs. J. K. M. Dickie, D. Maxwell Ross, W. F. Buist, J. Henderson, and Ninian Bruce for kind assistance in obtaining the clinical notes of the cases.

SUMMARY.

Small, rapid deflections, expressing the tone of the skeletal muscle may be present in the electrocardiogram.

These deflections can be differentiated from the slower deflections due to auricular flutter and fibrillation.

In *CASE I* the rhythmic auricular flutter at the rate of 250 to 300 per minute was studied by mechanical methods of registration and by electrocardiograms. By derivations II and III the curves were diphasic.

In ten cases of perpetual arrhythmia of the human ventricles, the action of the auricles was studied by means of electrocardiograms and mechanical registration. Jugulo-carotid tracings often reveal evidence of very rapid, irregular, feeble, auricular contractions. The electrocardiograms from all the cases presented irregular oscillations whose rates ranged in the several cases from 390 to 522 per minute.

In dogs whose auricles had been subjected to faradisation similar frequent and irregular oscillations at the rate of about 612 per minute were recorded in electrocardiograms.

Electrocardiograms from cases of perpetual arrhythmia of the human ventricles and from animals whose auricles have been submitted to faradisation agree with those in *CASE I* in presenting a series of frequent, small deflections in place of the usual summit *P*. They differ from them, however, in the irregularity of the waves and in their greater rate. Moreover, by no derivation do they shew a diphasic appearance. The two sets of waves are not identical. Those in *CASE I* are regarded as evidence of auricular flutter; those in perpetual arrhythmia of the human ventricles and in animals whose auricles had been subjected to faradisation may be attributed to fibrillation of the auricles.

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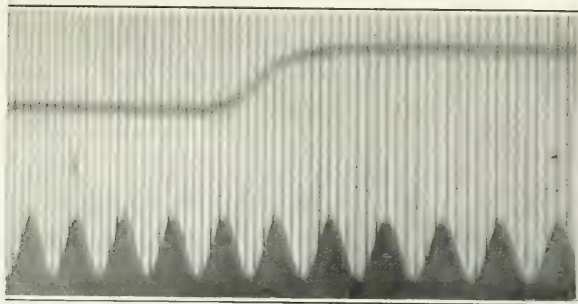


FIG. 12.

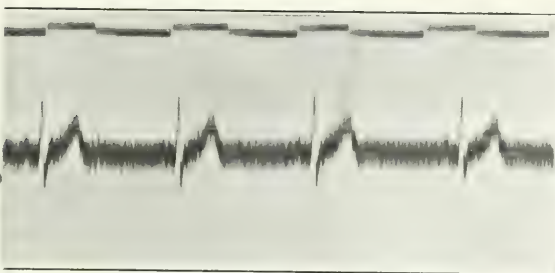


Fig. 13. Deflection of 2.2×10^6 are not regular. 10^{-11} Amp.

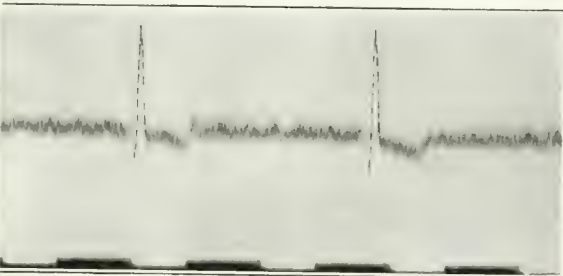


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Fig. 14. Electro-auricular wave is seen at

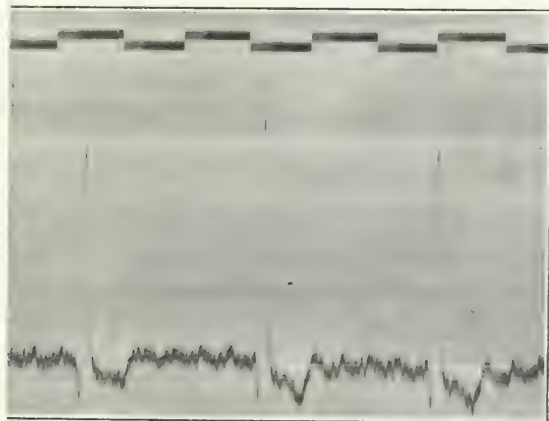
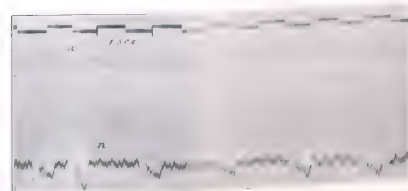
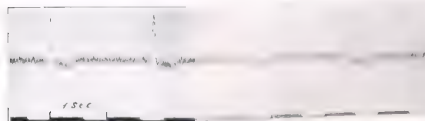
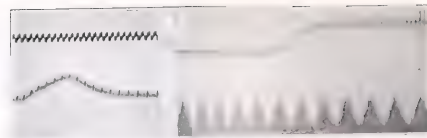


FIG. 14.



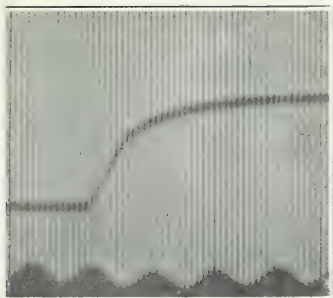


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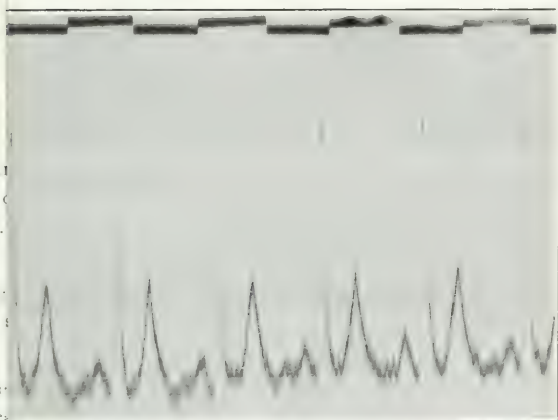


FIG. 16.

Fig. 18. Elec
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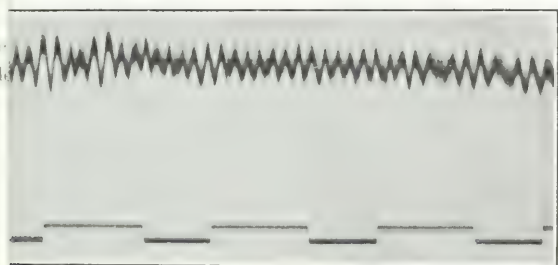


FIG. 17.

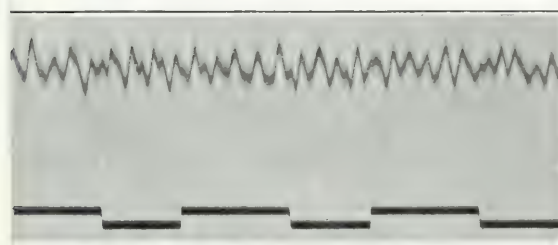
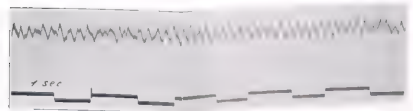


FIG. 18



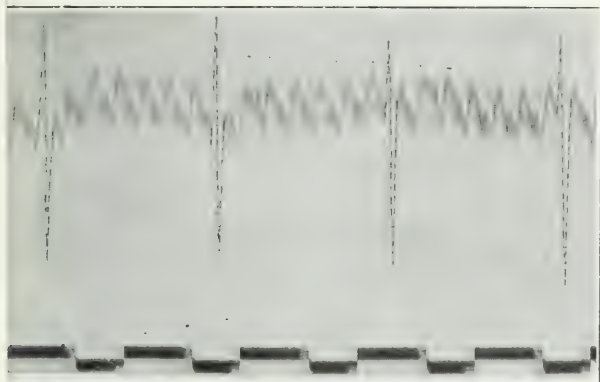


FIG. 19.

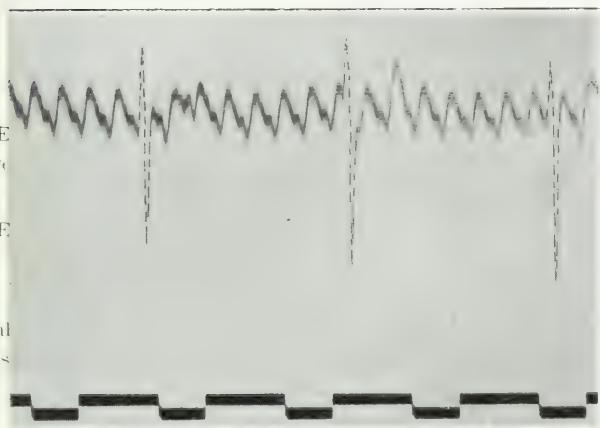


FIG. 20.

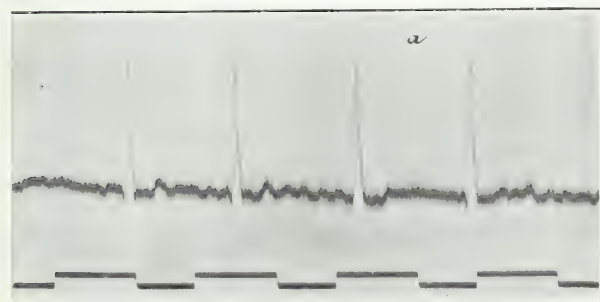
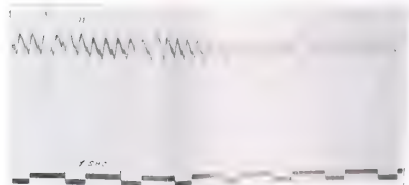


FIG. 21.



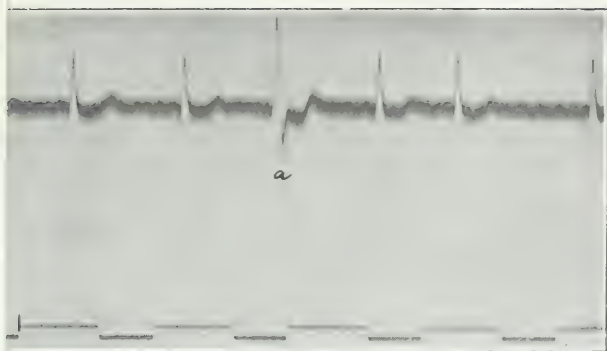


FIG. 22.

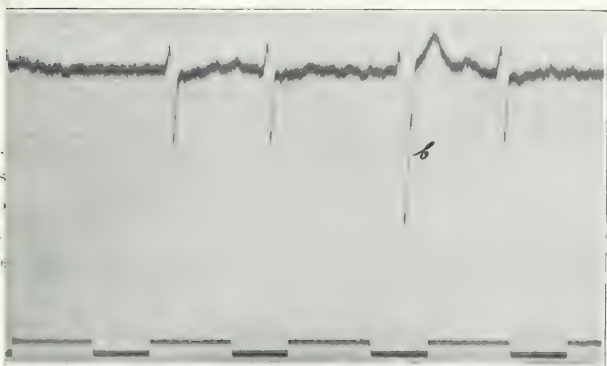


FIG. 23.

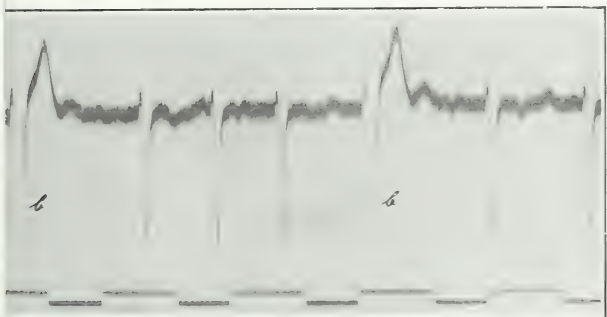
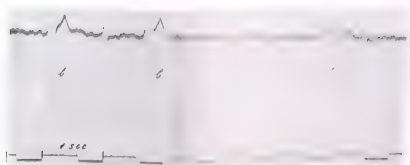


FIG. 24.

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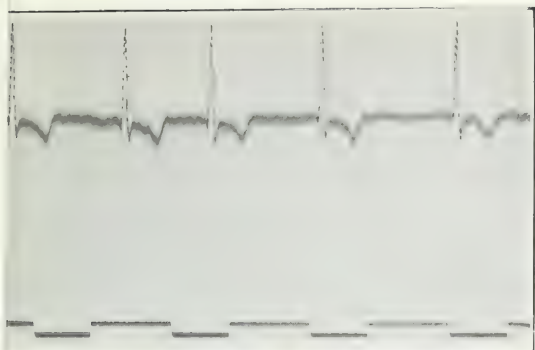


FIG. 25.

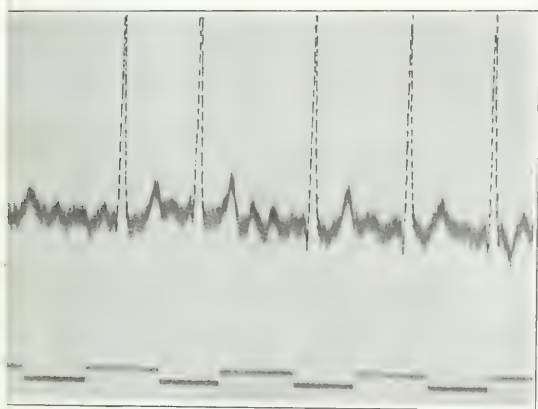


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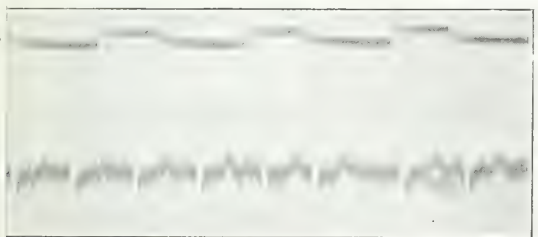
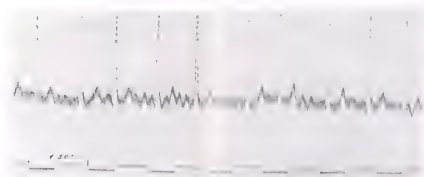
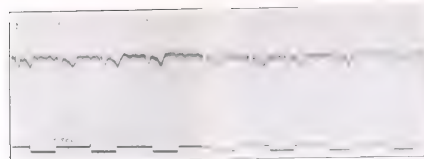


FIG. 27.



FIG. 28.



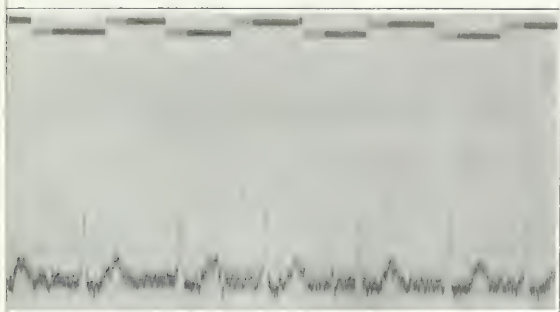


FIG. 29.

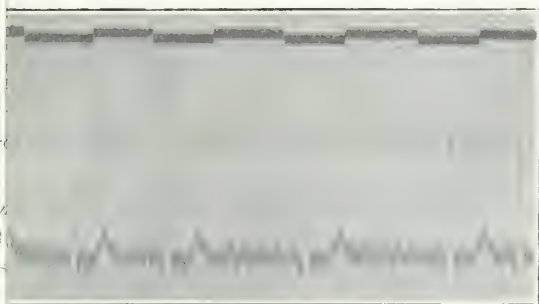


FIG. 30.

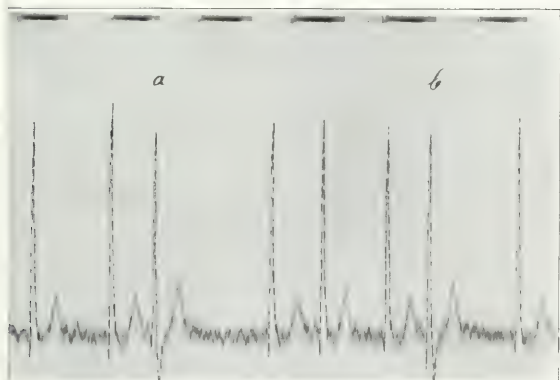


FIG. 31.



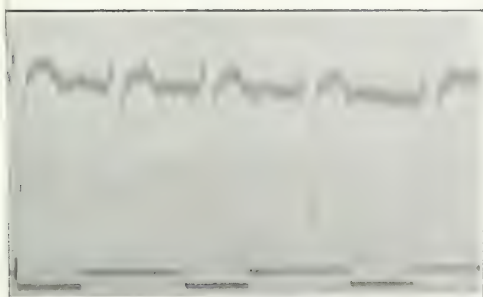


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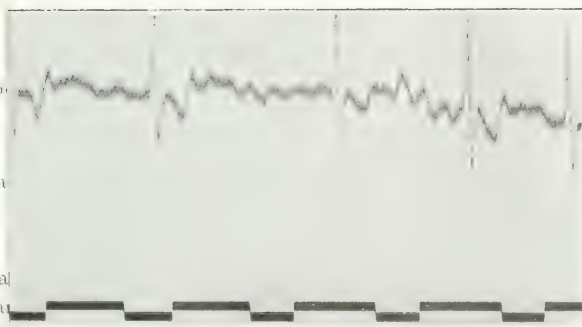


FIG. 33.

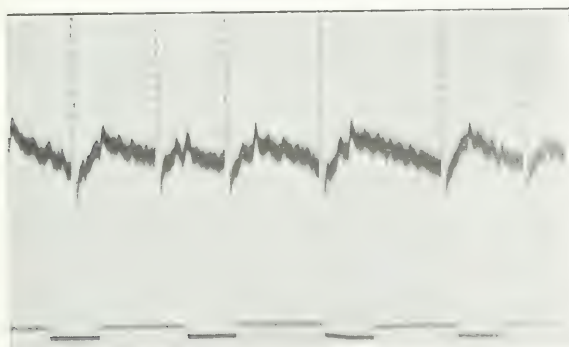
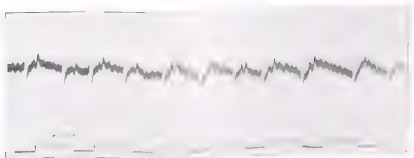
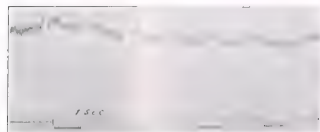


FIG. 34.



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OBSERVATIONS UPON TWO CASES OF STOKES-ADAMS
SYNDROME. UNASSOCIATED WITH DEMONSTRABLE DELAY
OF IMPULSE TRANSMISSION.

By ASHLEY W. MACKINTOSH AND A. W. FALCONER.

(Aberdeen).

CASE I. P. C., male, aged 55. Admitted into the Aberdeen Royal Infirmary under Dr. Ashley W. Mackintosh on the 26th November, 1909.

Previous History. There was no history of any of the specific fevers and no rheumatic history. There was no history of venereal disease. The patient was married and had several healthy children; his wife had had no miscarriages. There was no history of abuse of alcohol but the patient had always been a heavy smoker, at one time smoking as much as seven ounces of black tobacco a week. All his life he had been a labourer and had worked hard. Six years ago he was buried up to the chest in a sand slip whilst digging a tunnel. He was soon removed; no bones were broken, but he said that he had never done a full day's work afterwards.

Present Illness. During the three years prior to examination the patient had been subject to attacks of loss of consciousness. At first they were very infrequent, but at a later date they had been more frequent and he thought he had had from 20-30 altogether. The total duration of the individual attacks was 5 or 6 minutes. At times he knew they were coming on, as he experienced dimness of vision, and had time to sit down before losing consciousness. Frequently, however, he had no warning and several times had slightly injured himself by falling. During the attacks he was quite unconscious, but he had never been convulsed neither had he passed water during an attack. He thought the attacks were brought on by carrying weights or doing heavy work. During the few weeks prior to admission he had suffered a good deal from pain in his head, mostly in the frontal region. He had had no pain in the chest. For several years his sight had been failing, as a result of cataract. There had been no vomiting. He had not noticed any trouble with his breathing, even when going up a moderately steep hill. There had been no swelling of his feet. His chief complaint, apart from his headaches and attacks of unconsciousness, was that he was always tired, even after a good night's rest.

Present state. On admission the patient appeared to be perfectly comfortable in bed and could lie in any position without discomfort. His hair was very grey, and he looked considerably older than his years. The pulse on the 26th and 27th November was about 55 per minute and very irregular both in time and force. On the 28th November the pulse was much slower and perfectly regular, beating between 32 and 36 per minute. During his stay in hospital the heart maintained the slow regular rhythm, the rate varying from 32 to 36 beats per minute.

On the 28th November the chest presented the following features :—

On inspection, the neck showed a marked difference in the pulsation on the two sides. On the left side the only pulsation to be seen was a big heave synchronous with the radial pulse and obviously due to the carotid. On the right side the pulsations were much more numerous and more irregular but they could not be timed with any accuracy. The apex beat was neither visible nor palpable. The superficial cardiac dulness was diminished. On auscultation the sounds at the apex were best heard in the 5th space one half inch inside the left nipple line. The sounds of the apex were pure. At the base the sounds were also pure, but the 2nd aortic was considerably accentuated. All over the præcordium, but especially over the base and over the right side of the neck, in addition to the normal "lub dup," an additional sound could be heard frequently. It bore no constant relation in time to the normal sounds of the heart and it was best heard when it immediately followed the normal heart sounds. It was constant in character, of low pitch, and resembled a short first sound. The lungs presented signs of some emphysema. The radial arteries were markedly degenerated. The retinal arteries could not be seen owing to extensive lens opacities. The systolic blood pressure was 175 mm. (Riva Rocci). There was no polyuria and no albuminuria. Haig's modification of Wassermann's reaction was negative. Nothing abnormal was discovered in the abdomen or in the nervous system.

Tracings were taken with Mackenzie's polygraph on November 27th when the heart was beating irregularly at about 55 per minute. For short periods the heart would beat regularly, and during these periods a perfectly normal tracing was obtained with an *a-c* interval of just one-fifth of a second. There was, however, in most of these more or less regular periods a certain amount of sinus irregularity. Throughout the tracings an auricular extrasystole occurred on six occasions. All of the six auricular extrasystoles were followed by a normal period,* but in 5 of them the auricular extrasystole was succeeded by an independent ventricular systole (Fig. 1), the *a* and *c* waves falling together, and giving rise to an obviously compound wave. On the sixth occasion this did not occur, the auricular extrasystole being followed by a normal cardiac cycle. On all occasions the duration of the

* Owing to the slight sinus irregularity present, it was difficult to be certain of the "normal" period, but on every occasion the period following the extrasystole was exactly equal to either the preceding or succeeding period.

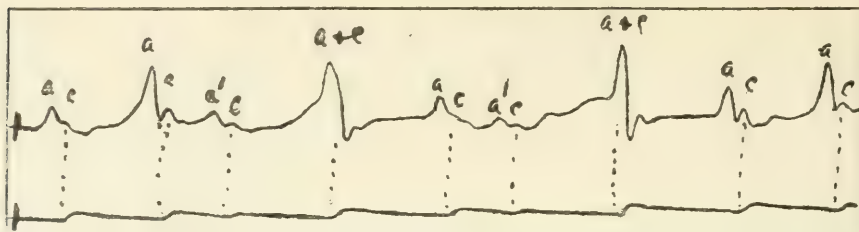


Fig. 1. $\times \frac{5}{6}$ linear. Shows two auricular extrasystoles with ventricular responses followed by independent ventricular contractions, the *a* and *c* waves falling together. In the auricular extrasystoles the *a* - *c* interval is not increased.

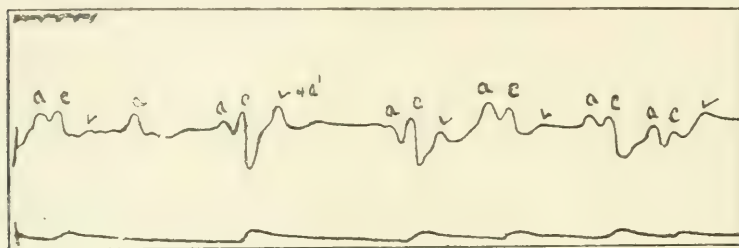


Fig. 2. $\times \frac{5}{6}$ linear. Shows two long pauses the first due to an isolated block between the auricle and ventricle, the second to a blocked auricular extrasystole (or possibly a stoppage of the whole heart).

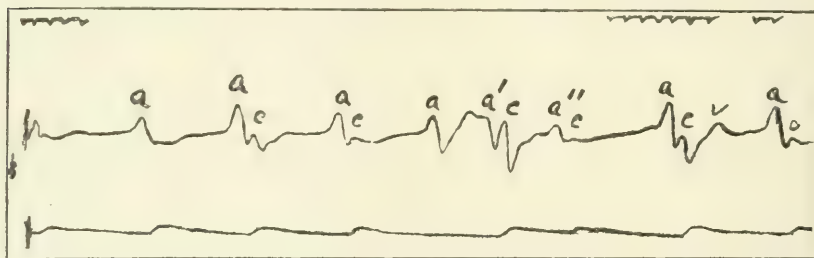


Fig. 3. $\times \frac{5}{6}$ linear. Shows an isolated block between the auricle and ventricle followed by two auricular extrasystoles.

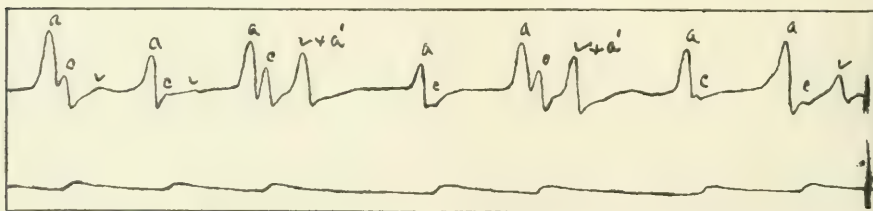


Fig. 4. $\times \frac{5}{6}$ linear. Shows a long pause due to a blocked auricular extrasystole—or possibly a stoppage of the whole heart. Certain of the *v* waves are peculiarly prominent.

auricular extrasystole and the preceding normal cardiac cycle was exactly two seconds.

On two occasions a pause was produced by an isolated intermission of the ventricles, the *a* waves appearing in their normal positions, but no traces of a *c* wave either in the phlebogram or in the radial tracing. In one of these pauses the duration was exactly two pulse periods (Fig. 2), in the other the dropped beat was followed by two auricular extrasystoles (Fig. 3).

The most frequent irregularity on this date was caused by an apparent stoppage of both auricles and ventricles. These stoppages occurred quite

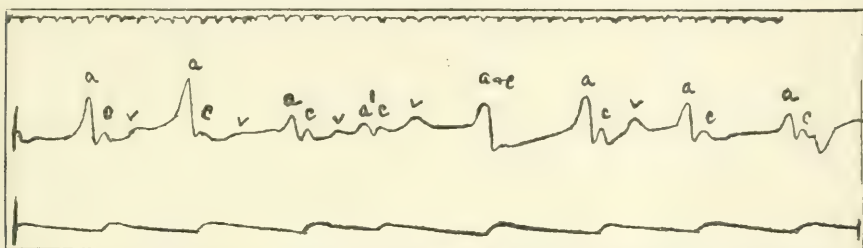


Fig. 5. $\times \frac{1}{2}$ linear. Shows similar pause to Fig. 4 but the *v* wave is not unduly large.

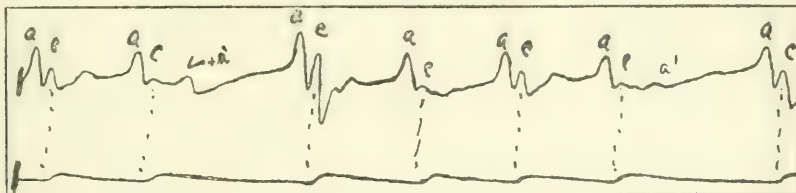


Fig. 6. $\times \frac{5}{6}$ linear. Shows auricular extrasystole—the distance from *a'* to *a* being exactly equal to the distance from large *v* to *a* in Fig. 4.

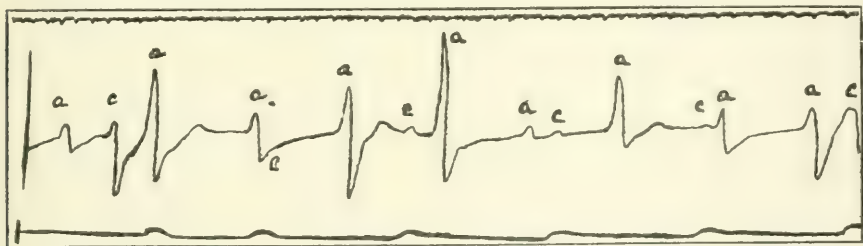


Fig. 7. $\times \frac{5}{6}$ linear.* Shows complete dissociation between the auricle and ventricle.

irregularly and were all of exactly two seconds duration.† In some of these pauses the *v* waves, though occurring exactly at the same time as the rest of the *v* waves throughout the tracing, are more prominent than most of the other *v* waves (Fig. 4). Apart from the large *v* waves there was in none of

* In reproducing, the first radial wave has been displaced to the right so that it no longer corresponds to the *c* wave in the phlebogram.

† In the tracings shown (Fig. 2, 4 and 5) the time-marker had temporarily ceased to record clearly; the measurements are taken from similar pauses of exactly the same length with a definite time record.

these pauses any sign of contraction of either the auricle or ventricle. The prominence of the large *v* waves, and the fact that the pauses are of the same length and exactly equal in duration to the auricular extrasystoles and the preceding cardiac cycles, suggest strongly the probability that the pauses are due not to a stoppage of the whole heart, but to the occurrence of a blocked auricular extrasystole as in the case described by Lewis.⁷ In favour of this view also is the fact that the pauses from the large *v* to the succeeding *a* wave are of the same duration as the pauses from *a*¹ to *a* in Fig. 5. It may, however, be noted that, in the majority of these pauses, the *v* wave is only slightly, if at all enlarged, Fig. 6. That these pauses are not due to a sino-auricular block is shown by the fact that the pauses are two-fifths of a second less than two pulse periods, and there is no shortening of the succeeding *a-c* interval to account for this. Stokes⁸ has recorded a case of pure sinus arrhythmia in which pauses of equal duration occurred with great regularity.

Within an hour of these tracings being taken the house-physician reported that the pulse had fallen to 34 per minute, and was perfectly regular. On tracings being taken next day, November 28th, the pulse was beating with perfect regularity at 33.3 per minute, and there was now complete dissociation between the auricle and ventricle, the auricle beating at 54.5 per minute and the ventricle at 33.3 per minute (Fig. 7). The auricle, therefore, was maintaining the same rate as on the previous day while the ventricle was beating with its own rhythm. The patient remained in Hospital for three weeks, and numerous tracings were taken; they all showed complete dissociation between the auricle and ventricle.

CASE II. Male, age 74, seen with Dr. Wilson of Huntly.

For three years the patient had suffered from attacks of giddiness and loss of consciousness, and was known to have had a very irregular pulse. The attacks of unconsciousness had sometimes been very numerous, but at times ceased for several months. For some weeks before examination the attacks had been coming many times a day. On examination the patient presented the signs of moderate arterio-sclerosis, and there was a slight mitral systolic murmur. Owing to the fact that the patient lived at a considerable distance in the country under conditions very unsuitable for graphic examination, the tracings were obtained only on one occasion. At the outset the pulse was beating regularly at 56 per minute, and the tracing showed a normal phlebogram with an *a-c* interval of rather less than one-fifth of a second. This rhythm having continued for some 15 minutes the tracings 8-10 were obtained in the space of 10 minutes. This irregular period was followed by a normal heart action which lasted throughout the remainder of the visit. During the long pause in Fig. 8, the patient probably lost consciousness. In the midst of a normal heart action the ventricles suddenly ceased to respond to the auricular stimuli and the ventricles remained silent for over 11 seconds. The auricle continued to beat rhythmically

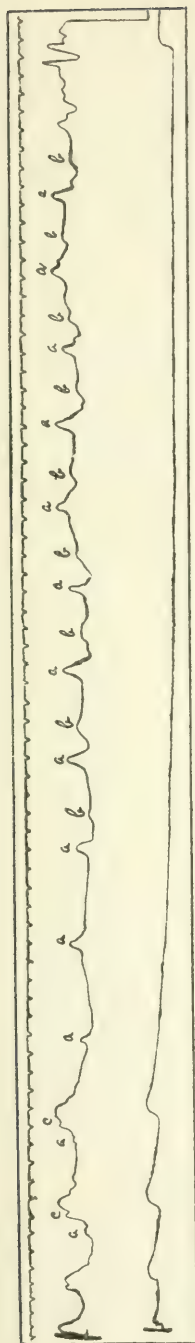


Fig. 8. $\times \frac{5}{8}$ linear. Shows stoppage of ventricles for over 11 seconds, and presence of a well marked *b* wave.

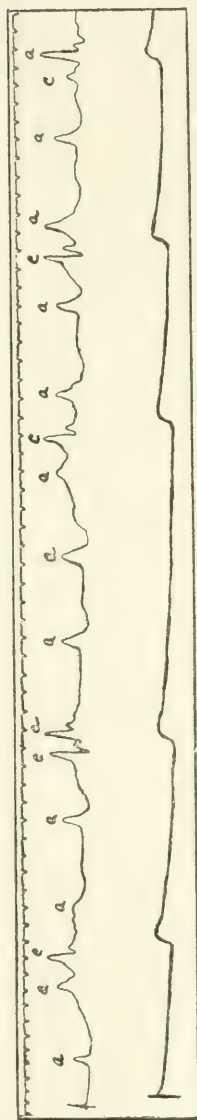


Fig. 9. $\times \frac{5}{8}$ linear. Shows either complete dissociation or a high grade of heart block with slow irregular ventricular rhythm.

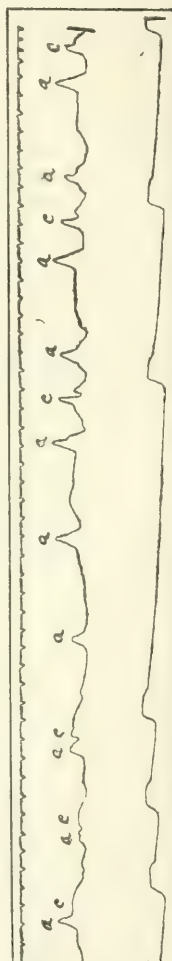


Fig. 10. $\times \frac{5}{8}$ linear. Continuation of Fig. 9, showing responses of ventricle to auricle.

though towards the end of the pause, the auricular rate increased somewhat. The phlebogram, besides exhibiting a gradual rise in height towards the end of the tracing, shows a well-marked wave *b*. This wave was well marked in a similar pause which occurred a few minutes later, and also more irregularly at times in which for brief periods there was either complete dissociation between the auricle and ventricle or a high grade of heart-block with a slow irregular ventricular rhythm. Similar waves have been described by Gibson³ and Griffith and Cohn.⁵ Gibson in his case attributes the wave to a contraction of the superior vena cava, and explains its long separation from the succeeding *a* wave by presuming a defective conductivity between the superior vena cava and the right auricle. Griffith and Cohn, with whom we agree, attribute their wave to the influences which cause the diastolic wave of Gibson and Hirschfelder. With regard to the broadening out of the *a* wave during the pause and its apparent compound character at the end of the pause, Wenckebach¹⁰ has suggested that the difficulty in many tracings in estimating the precise moment at which the *a* wave begins is due to its being compound, the first and smaller rise being attributed to the contraction of the superior vena cava. Here, however, the first portion of the wave is the more prominent. During the ten minutes in which the heart was beating irregularly, several tracings similar to Fig. 9 and 10 were obtained. They show either complete dissociation or a high grade of partial heart-block with a quite irregular ventricular rhythm. Within a few minutes, those irregularities completely disappeared and although the tracing was continued for half-an-hour the pulse remained perfectly regular with a normal *a-c* interval. The patient was treated with atropine sulphate gr. $\frac{1}{100}$ three times a day, and while for weeks before treatment he had experienced very numerous and daily attacks of unconsciousness, the attacks subsequently ceased, and although he lived for three months, Dr. Wilson reports that he had no further attack until the day of his death, when the patient's wife considered that he died in a fit. For some weeks before his death he showed a certain amount of dyspnoea and œdema and developed a pneumonia; no post-mortem examination was permitted.

In *CASE I* we have complete dissociation between the auricles and ventricles with a normal *a-c* interval during periods of normal sequence. 4

We may emphasise the fact that on the day previous to complete dissociation, the conductivity and excitability were sufficiently good to permit of the occurrence and transmission of frequent auricular extrasystoles. In *CASE II* there was also no sign of impairment of conductivity while ventricle responded regularly to auricle, and there appeared to be a very distinct improvement in the clinical symptoms under atropine.

Cases showing complete dissociation between auricle and ventricle at one time and a normal *a-c* interval at another have been reported by Gossage⁴ and Earnshaw.¹ In Earnshaw's case atropine administered during the period of dissociation and giving the full physiological effects, had no effect on the pulse, except for a single and temporary rise in rate. Gerhard² reports a similar case, but in some parts of his tracings there was a slight increase of

the *a-c* interval. Thayer and Peabody⁹ report a case in which dropped beats frequently occurred with no evidence of impaired conduction. The dropped beats could be readily produced when the pulse was normal by pressure on the vagus in the neck. Hay⁶ has recorded a case which, when first seen, showed heart-block with a long *a-c* interval, but which, when seen three months later, revealed a 2:1 rhythm and a normal *a-c* interval. Wenckebach¹⁰ has described a similar case in which every fourth and fifth ventricular contraction was dropped out. Hay and Wenckebach attribute these cases to diminished excitability either of the fibres of the auricular canal or of the ventricle.

Summary. A case is reported, which showed complete dissociation between auricle and ventricle, supervening within an hour of a normal sequence of auricle and ventricle, a normal *a-c* interval, and presenting auricular extrasystoles and long pauses probably due to blocked auricular extrasystoles.

A second case is reported which showed the sudden passage of a normal sequence with a normal *a-c* interval to a high grade of heart-block associated with prolonged pulse pauses.

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THE EFFECT OF ROOM TEMPERATURE UPON THE BLOOD-FLOW IN THE ARM, WITH A FEW OBSERVATIONS ON THE EFFECT OF FEVER.

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(*Department of Internal Medicine, University of Michigan.*)

It has long been recognised that the blood vessels near the surface of the body dilate under the influence of heat and contract under the influence of cold. Records of these vascular changes in man may be made with the plethysmograph,⁵ the volume pulse recorder,⁷ or the flame tachograph;¹ but the interpretation of these records, quantitatively in terms of blood-flow, has not been satisfactory. Nor can the variations in flow that are produced in animals by thermic influences² be transferred quantitatively to man; for the reason that in man, the extremities are relatively large, and the peripheral vessels play a much more important part in maintaining a constant body temperature.


Method.

The present studies were therefore undertaken with the hope of defining more accurately the degree to which variations in room temperature might affect the peripheral flow of blood in man. The subjects of the experiments, stripped to the waist, lay quietly in a small room which could be easily heated and cooled. The former was accomplished by hot furnace air assisted by a gas stove; the latter by opening the windows and allowing the cold winter air to enter the room. The rate of blood-flow in the arm was determined by the method described by Hewlett and Van Zwaluwenburg.³ * Subjects were purposely chosen who showed considerable individual variation in the rates of blood-flow in the arms. Very rapid rates were represented by CASE 5, a patient with exophthalmic goitre, and by CASE 6, a patient with extreme vasomotor instability. CASE 9, a severe diabetic showed an abnormally slow rate.

* We find that this method had been previously suggested by Brodie and Russell,² though they do not seem to have published results from its use. The same principle has been employed recently, though not very successfully, by Levy.⁶

Since the object of the experiments was to determine the rate of peripheral blood-flow during ordinary variations in external temperature, exposures to excessive heat and to excessive cold were avoided. The range of temperatures usually varied from those which produced sensations of slight chilliness (17° - 21° C) in the half-exposed subjects, to those which caused an uncomfortable feeling of warmth followed by perceptible perspiration (27° - 31° C). The indifferent room temperature, at which neither coolness nor warmth were experienced, usually lay in the neighbourhood of 22° to 24° C. The air surrounding the arm in the plethysmograph was usually 2° to 4° warmer than the air in the room, and during a long experiment it often became saturated with moisture. These differences however, appeared to have had little influence upon the results obtained; for on several occasions, a change to drier and slightly cooler air in the plethysmograph produced no essential change in the rate of blood-flow.

Results.

 The main results of the experiments upon variations of room temperature are shown in Fig. 1-4. An original tracing is shown in Fig. 8. The individual points on the charts usually represented averages of two or more determinations of the blood-flow at a given temperature. This averaging of determinations has tended to make the charted curves more regular than the individual findings, for the fluctuations of flow caused by psychic and other transitory vasomotor influences have been eliminated to some extent.

The effect of varying room temperatures upon the blood-flow in the arm will be discussed under three headings: 1) those occurring when the person felt neither too warm nor too cold, 2) those accompanying chilliness and the warming up after chilliness had occurred, 3) those leading up to perspiration and associated with the cooling after perspiration. Changes of the first class are shown in Fig. 1. When the individual was already comfortable and the room was heated, there was usually a gradual and fairly uniform increase in the rate of blood-flow in the arm. This seldom exceeded 50 per cent. up to the time that the individual began to be conscious of an uncomfortable warmth. In *CASE 2*, (Fig. 1 second dotted line) the room was again cooled before the subject began to feel uncomfortably warm and the rate fell much as it had risen. Fig. 3, curve *a*, illustrates the effect of reducing the temperature of the room from the comfortable point to that producing decided chilliness and beginning shivering. The rate fell to about half what it had been: a fall which seemed even less when it is compared with the rates (*b* and *c*, Fig. 3) taken on other days from this patient. Similar drops in rate of less than 50 per cent. are shown in Fig. 4, when the individuals were subjected to rapid lowering of room temperature. When the person was slightly chilly and the temperature of the room was gradually raised, the rate of blood-flow often remained low for some considerable time. This is clearly shown in

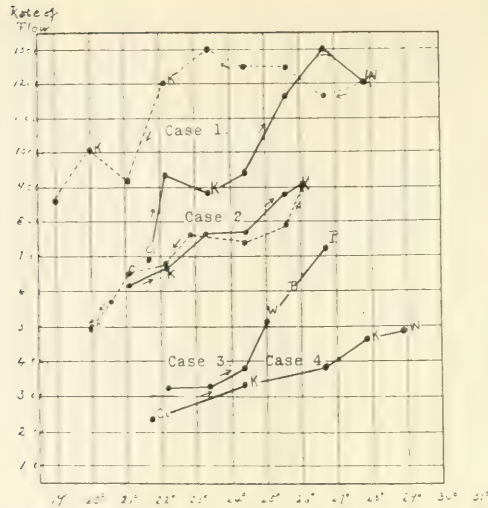


Fig. 1. The effect of varying room temperatures upon the blood flow in the arm. The two upper are from patients with pernicious anaemia, the two lower from normal individuals. Rates of flow are expressed in terms of c.c. of flow per minute per 100 c.c. of arm volume. Sensations in this and the following figures are indicated by the abbreviations, *Ch.*=chilly; *Cl*=Cool; *K*=comfortable; *W*=uncomfortably warm; *P*=beginning perspiration; *B*=indicates that subject was covered with a blanket. The arrows indicate the direction in which the curves should be read.

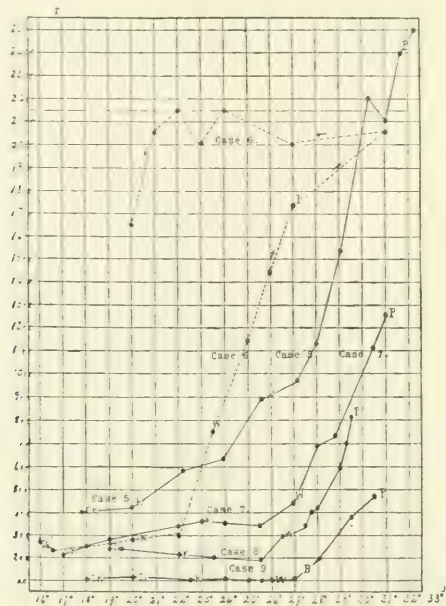


Fig. 2. Effect of passing from chilliness to beginning perspiration owing to changes in room temperature. *CASE 5*, Exophthalmic goitre; *CASE 6*, marked vasomotor instability in a patient with pleurisy; *CASE 7*, normal; *CASE 8*, Neurasthenia with cold extremities; *CASE 9*, severe diabetes.

Fig. 3 curve *c*. (identical with *CASE 8*, Fig. 2). The room was warmed very slowly and during the hour consumed in raising the room temperature from 19° to $25\frac{1}{2}^{\circ}$ the rate fell gradually, approximating that found on another day when the patient had been made chilly by cooling the room. This same tendency for the peripheral flow to undergo but little change when a rising room temperature acts on an already chilly individual is shown in Fig. 2. Here the persons were placed in a cool room and the latter was gradually heated until a feeling of warmth followed by perceptible perspiration was produced. In *CASES 6, 7, 8, 9*, the rate remained almost stationary up to the point when the person began to feel uncomfortably warm. The failure of the rate to rise during this period was probably due to the previous chilliness. At about the time that uncomfortable sensations of warmth began to be experienced, the rate rose rapidly and by the time that visible perspiration had appeared it usually became four or five times the original rate. This rapid increase in the rate of flow which accompanied the sensation of warmth and beginning perspiration was the most characteristic feature of this group of experiments. In only one patient, a stout diabetic, (not charted) did we observe a feeling of warmth and beginning perspiration associated with no decided increase in the blood-flow through the arm. When the room was cooled after the person had begun to feel uncomfortably warm, (Fig. 1, *CASE 1*), or after perspiration had already started (Fig. 2, *CASE 6*), the flow did not diminish along the line it had ascended but it remained relatively higher at a given temperature than it had been during the heating of the room.

A few tests were made on the effect of sudden exposures to high and to low room temperatures (Fig. 4). The exposure to cold was followed by a moderate drop in rate. In two of the three cases exposed to heat the blood-flow accelerated rapidly but in the third case the patient did not feel particularly warm and his rate did not increase during the 11 minutes that he was exposed to a room temperature of 29° C.

Discussion of foregoing results.

These observations demonstrate to what a large extent the rate of blood flow in the arm, and presumably in other parts of the periphery of the body, depends upon the temperature of the surrounding air. Thus far we have found no other factor, except local exercise, which will influence the rate of blood-flow in the arm to the same extent as do thermic influences. The moderate variations when the individual feels comfortable, and the extreme variations of 400 per cent. or more when the individual passes from chilliness to beginning perspiration should be kept in mind in all studies of the peripheral circulation. Even though all observations of the blood-flow are made at a given room temperature the previous state of chilliness or warmth and

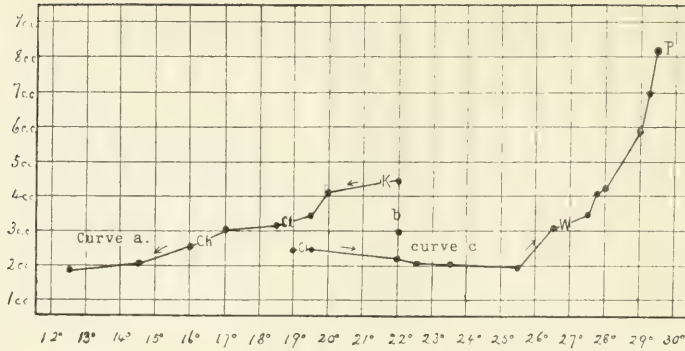


Fig. 3. Observations on a single individual. (CASE 5 of preceding figure).
 a. Passing from comfort to marked chilliness.
 b. Comfort.
 c. Passing from coolness to beginning perspiration.

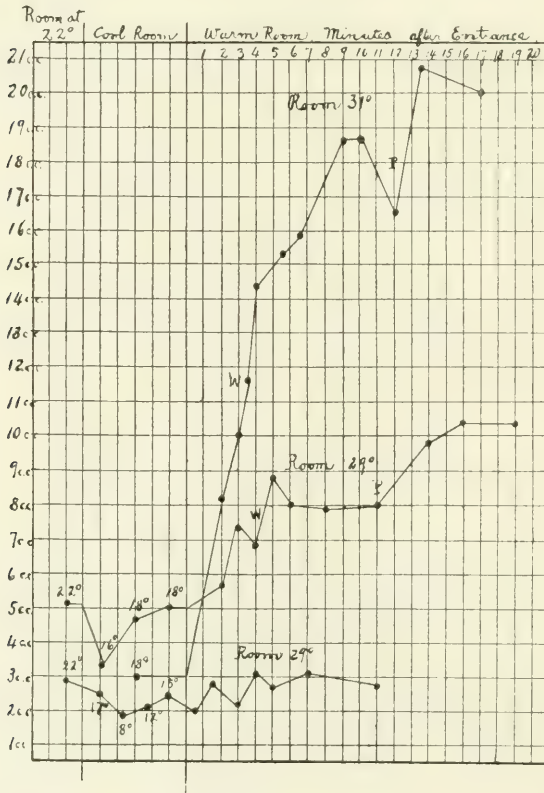


Fig. 4. Effect of passing abruptly from comfortable to cool rooms and from these to warm. The uppermost is CASE 6, Fig. 2; the middle a normal individual; the lowest, CASE 8, Fig. 2.

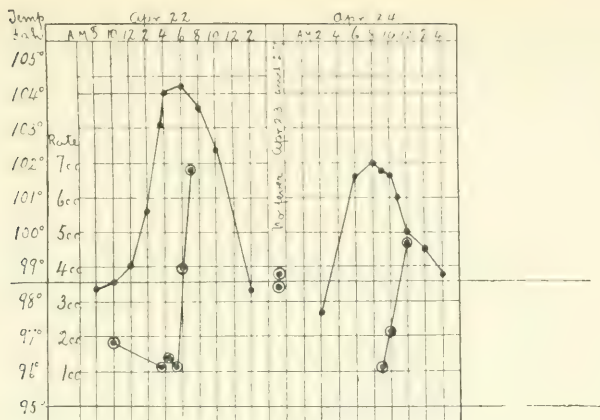


Fig. 5. Variations of blood-flow in arm during abrupt febrile rises and falls of temperature.

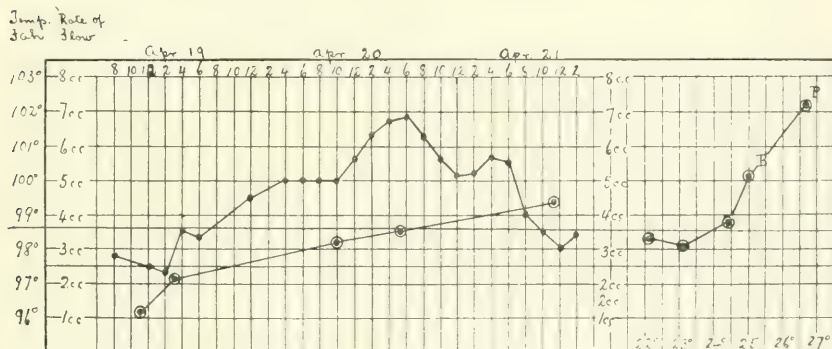


Fig. 6. To the left, variations of blood-flow in the arm during slow febrile rises and falls of temperature. To the right, variations of blood-flow in the arm of same individual when afebrile; due to varying room temperature.

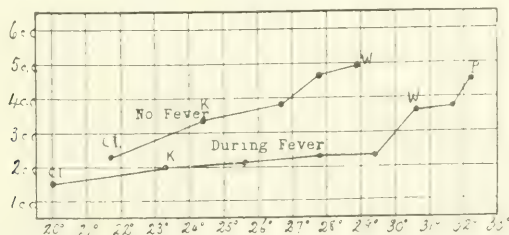


Fig. 7. Effect of external temperature upon blood-flow, upper curve taken during afebrile stage and lower curve just after the summit of a tuberculin reaction (temp. 101.6 degrees Fah.)

the possible influence of other factors (general exercise, meals, etc.), may cause variation in the rate of flow.

These variations in the peripheral circulation under thermic influences constitute the so-called physical method of regulating the body temperature. Physiological studies have shown that these variations in the size of the peripheral blood vessels are caused in the main by nervous influences proceeding from the heat regulatory centre in the brain. Considerable discussion has arisen as to the nature of the influences to which the heat regulatory centre normally responds. These may consist either of centripetal impulses from the skin excited by the sensations of heat and cold¹⁰ or of changes in the temperature of the blood circulating through the centre.⁵ The former certainly play an important part in the usual variations of peripheral blood-flow but we do not know to what extent the latter normally acts. The results of this study may be interpreted in accordance with either hypothesis.

Although these circulatory changes are essentially local in character, being due to variations in the calibre of the peripheral blood vessels, their effect on the general circulation must in some case⁵ be very considerable. As an extreme instance we may take that of *CASE 6* with a minimum rate of 2.4 c.c. per minute per 100 c.c. of arm substance and a maximum rate of 21.5 c.c.. If we assume that the same rate prevailed in the legs and estimate the volume of all extremities at 10,000 c.c. then the amount of blood flowing through all these varied from 240 c.c. per minute when the subject was chilly to 2150 c.c. per minute when he was perspiring. If we assume furthermore that the output from the heart was 70 c.c. of blood at each systole then the output in a minute, at the heart rate of 94, was 6680 c.c.. It is evident from this rough calculation that the great variations in the peripheral blood flow, which approximated 30 per cent. of the total during perspiration, must influence the general circulation very considerably. Studies on man have shown that blood is diverted from the abdomen and possibly from the brain to the periphery under the influence of the external application of heat⁸ and studies on animals have shown that the flow through the splanchnic vessels is diminished⁸ under these conditions. To what extent the work of the heart is influenced we do not know.

Fig. 2 shows a number of interesting individual differences when persons pass gradually from chilliness to beginning perspiration. *CASE 5*, the patient with exophthalmic goitre, showed a relatively high rate of flow at all temperatures. This observation together with a number of new observations on patients with this disease¹ supports our view that the increased peripheral blood flow is a characteristic circulatory change in this disease. *CASE 6*, a young man who showed marked vasomotor instability and easily aroused flushings, gave most extreme variations in the blood-flow through the arm. This began to rise at a relatively low temperature and perspiration appeared early. In contrast to these two individuals we have *CASE 9*, an emaciated diabetic of the severe type who showed throughout an extremely slow rate of flow

such as is common in emaciated persons with cool dry skins. His rate did not increase with the rising temperature until after he had been covered with a blanket at 27.5°.

The Peripheral Blood-Flow in Fever.

It is difficult to determine the effect of fever upon the peripheral blood flow because of several variable factors. In the first place the variations in the blood-flow of different individuals makes it necessary to compare the flow during fever with the flow in the same individual during apyrexia, especially after the individual has completely recovered from his infection. In the second place variations caused by the room temperature and possibly by other factors (diet) must be taken into account and this is the more difficult for the reason that persons with fever probably react somewhat differently to such influences, as is suggested especially by the ease with which they become chilly on exposure. Finally the peripheral rate during fever is subject to variations according as the body temperature is rising or falling. The extent to which the peripheral blood-flow may vary during variations in body temperature is shown in Fig. 5 and 6. The former shows the results obtained during two short paroxysms of a fever that was caused by sepsis. The first rise of temperature was accompanied by some chilliness, otherwise there were neither chills nor sweats. The rates of peripheral flow on two afebrile days were 3.4 c.c. and 3.8 c.c. respectively. During the rise of temperature in the first paroxysm a very marked constriction of the peripheral vessels occurred, the rate falling to the unusually low figure of 1.1 c.c. This lasted up to the summit of the fever curve in the first paroxysm and apparently a little beyond it in the second paroxysm. With the rapidly falling temperature the rate rose moderately above the normal rate. Fig. 6 represents a much longer paroxysm of fever with similar changes in the rate of blood-flow through the arm. For comparison there has been inserted the change in flow which occurred in this patient during an afebrile period when the room was heated from the comfortable point to that which caused perspiration. Fig. 7 shows the comparative effect of heating the air of a room during apyrexia and just after the summit of a tuberculin reaction. In the latter the rate of flow was slower at all temperatures, possibly because the vessels had not yet dilated after the rise of fever; possibly however because they reacted excessively to the cool air.

The impression that we have derived from these observations and from several determinations during the height of continuous fevers is that the peripheral blood current during fever is on the whole somewhat slower than in health. Up to the present however we have not been able to obtain observations free from the many possible errors already enumerated. It is

certain that the peripheral flow in fever is altogether different from the peripheral flow when the temperature of the body has been artificially raised by the external application of heat. In the latter case as was shown by Hewlett and van Zwaluwenburg³ the peripheral circulation is enormously increased just as it is when the person sweats owing to the high temperature of a room. In fever the vessels still dilate under the influence of external heat (Fig. 7) but the heightened temperature of the body does not influence the heat regulatory mechanism in such a way as to cause their dilation.

CONCLUSIONS.

1. Ordinary variations in the external room temperature produce marked effects upon the rate of blood-flow in the arm.
2. The rate of flow when external warmth causes perspiration is often five or more times the rate when the person feels chilly.
3. Perspiration caused by a warm room is usually preceded or accompanied by a sudden acceleration of the flow.
4. The previous state of warmth or chilliness influences the flow at a given external temperature.
5. The flow is exceptionally slow when the temperature rises during fever and is moderately accelerated when the temperature falls during fever.

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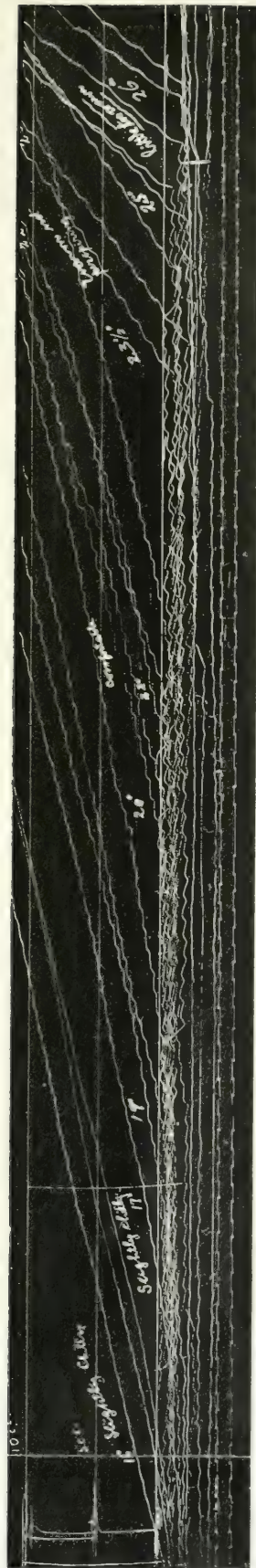


Fig. 8. $\times \frac{1}{2}$ linear. Tracings showing effect of heating room upon blood flow in arm. A portion of that charted in Fig. 2, C.I.S. B. 5.

REPORT OF A CASE OF TRANSIENT ATTACKS OF HEART-BLOCK, INCLUDING A POST-MORTEM EXAMINATION.

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1. *Clinical Record.*

The facts in regard to this case have been obtained through the kindness of Dr. H. Bazett of Hendon, to whom we are indebted for many observations upon the patient.

The patient was an old maiden lady of eighty, in poor circumstances. There was a history of rheumatic fever, from which she had suffered on two occasions, at the ages of 3 and 40 respectively. At the age of 56, she had three fits of an indefinite nature, otherwise her health had been good. She had lived a very active life, and even in old age was exceptionally energetic. There was a history of ulceration of the legs, preceding the latest attacks of giddiness. She used to suffer frequently from bilious attacks, during which she was occasionally affected by slight jaundice.

She was in fair health for many years until March, 1908, when following an attack of "influenza," fits stated to have been of a similar nature to those previously reported, recurred. She suffered from them daily for five weeks, as a rule there were four or five fits a day, the longest fits were of five minutes' duration. In October of the same year, she had a return of the attacks, and they were very numerous, at times amounting to as many as ten per day. There was a respite of two weeks, until three days before she was first seen, by one of the writers when the fits were again present. She was seen by Dr. Bazett during the last two series of attacks (October and November, 1908), and

* Working under the tenure of a Beit Memorial Research Fellowship.

the pulse was frequently found to be slow directly after the occurrence of the attacks (27-29 beats per minute). On both occasions there was marked dilatation of the heart directly after the fits.

I examined her on the 14th November, 1908, shortly after the subsidence of an attack, the pulse was found to be irregular at an average rate of about 55. The old lady was sitting up and seemed in a good state of preservation for her years. There were some chronic joint changes and a slight tremor of the hands. Cyanosis and other signs of cardiac failure were absent. The urine was normal.

The limit of the heart's dulness to the right was $1\frac{1}{2}$ inches from the mid-sternal line; the left limit of dulness about 4 inches from the same line. The heart's apex beat was in the fifth space and forcible. There was a loud systolic murmur at the apex; the first and second sounds were clear. The heart's sounds corresponded exactly to the pulse tracings. There was no evidence of premature contractions. Pulsation in the neck was rapid. The tracings showed occasional dropped beats, beats dropped every third cycle and every alternate cycle. The *a-c* interval was of normal length in all the curves. On the 15th, curves were taken and occasional missed beats were found.

On questioning the patient in more detail as to her symptomatology, she stated that she was warned of the onset of the fits by a disturbance of vision, and frequently by a feeling of faintness; that there was no precordial pain, but that when the pulse was slow, she was conscious of her heart beating. The friend who was nursing her stated that during the attacks, she became pale and subsequently blue, and that not infrequently there was twitching of the hands.

On November 18th, Dr. Bazett wrote: "I saw the patient yesterday, she had had several fits in the interval, but the pulse rate had not. I was told, been much affected. While I was there, the pulse rate was at first regular and normal, but missed three single beats in about five minutes. Suddenly she said she felt giddy, as if an attack was coming on, though I felt no change in her pulse, and while she was moving to lie down, four consecutive beats were missed, then everything went normally again and the feeling passed off. The heart was more dilated."

On November 21st, Dr. Bazett wrote: "The patient is well and the pulse normal." On the 22nd November, the pulse was irregular and various grades of partial heart block were present. As a rule 2:1 or 3:1 heart block was found, at other times, mixed periods of 1:1 and 2:1 ratios were present. Curves taken at this visit are shown in Fig. 1 and 2.

On December 11th the pulse was reported by the friend to have been at a rate of 27 beats per minute. Dr. Bazett wrote: "I went two or three hours after, when it was 42 and regular. Yesterday it had reached 50, to-day it is 60." There had been an interval of two weeks without attacks, and during the third week, there were only one or two very slight attacks. On the 17th December, Dr. Bazett wrote: "Three days ago the pulse

was 42 and regular, the day before yesterday it was 36 and most irregular. No fits or attacks of giddiness occurred. The patient was up and doing her work in her room. In the afternoon it was slow and later it quickened to normal." And again: "The nearest approach to a fit which I have seen is on one occasion upon which when counting the pulse and finding it normal, she said suddenly: 'I feel giddy, I feel as if an attack is coming on.' Still I felt no change in the pulse. I began to move her to a couch, and while doing so, three successive beats intermitted once, then the pulse became normal, and there was no fit."



FIG. 1 and 2.

On December 21st, Dr. Bazett wrote that there had been more fits and that the pulse was slow again. She had apparently had fits during the night, and in the morning, the pulse was regular, between 27 and 30 beats per minute. The friend examined her pulse during an attack and found it at the commencement very slow and irregular, but while the fit continued, it became faster. On December 22nd, 2:1 heart-block and occasional periods of 3:1 heart-block were recorded.

On August 29th, 1909, Dr. Bazett wrote to inform me that the patient was dying. She was said to have had many fits since the last report, of a similar nature to those already recounted. The pulse was generally very slow during the fits.

On August 28th, she fell heavily and struck her head. She became unconscious and her condition was critical. I saw her in the evening of the 29th. She was comatose, the limbs flaccid and the breathing stertorous, the temperature had been 101-104. She was obviously moribund and no curves could be taken. The pulse tension was high, there was a tendency to dirotism, the rate was about 90 beats per minute. Pulsation in the veins of the neck was very distinct and apparently of a perfectly normal form. Two small fluttering movements could be seen with each beat of the pulse, one of which appeared to be presystolic in time.

There had been numerous fits about a fortnight before the accident, and in one of these Dr. Bazett felt the pulse stop for at least one minute.

The patient died on the morning of the 30th August, 1909.

The repeated observations showed that the mechanism of the heart was usually normal, heart block in its several grades was only present at or about the times when fits occurred. *Th. L.*

II. *An account of the Post-Mortem Examination with Special Reference to the Heart.*

The autopsy took place on August 31st, 1909, twenty-four hours after death. The body was that of a moderately nourished woman.

The left temporal muscles and fasciæ showed hæmmorrhages, and they were oedematous. The brain showed sclerosis of the pial vessels of the cortex, but the basal vessels were healthy. Over the right parietal region there was considerable oedema; the pial membrane was not thickened. In the middle of this area, corresponding to the leg and trunk centres, there was a moderate amount of recent hæmorrhage. There was no hæmorrhage into the ventricles; the rest of the brain was without change. There were adhesion at both pulmonary *apices*, especially the left; the *lungs* themselves were voluminous, showed slight oedema and thickening and puckering of the pleuræ at the apices. The *liver* was normal in size, showed moderate stasis with fatty degeneration of the centres of the lobules; there was no cirrhosis. The *spleen* was small and showed some anthracosis. On the surface were two old infarcts measuring 2.3 centimetres in diameter and extending inward about 2 millimetres. They were of a yellowish-white colour and dense in their consistency. The *kidneys* were small, the capsules somewhat adherent. The vessels were prominent. There were no infarcts. The *gastro-intestinal tract*, the pancreas, and the genito-urinary apparatus were not examined. The right suprarenal capsule had already undergone softening; the left one was not examined.

The *heart* was enlarged; the length of the ventricles was 9 cm.; there was an excessive deposit of fat upon them. The right auricle was dilated, the endocardium whitened; there was a small Chiari net over the opening of the coronary sinus. The right ventricle was neither dilated nor hypertrophied; the tricuspid valve was slightly thickened. On the posterior flap of the pulmonary valve, a cauliflower-like vegetation, 5 mm. in diameter, was found. This had not the appearance of a recent lesion. The left auricle was dilated, but not hypertrophied; the endocardium was much thickened. The outflow tract of the left ventricle was dilated and the trabeculæ flattened. The papillary muscles were not hypertrophied, neither was the wall of the ventricle. There was slight retraction (inrolling) of the posterior flap, but both the flaps were thickened above the free edge; the aortic flap of the mitral valve showed marked thickening there was no stenosis. Except for slight thickening and fringe-like vegetations the corpora Arantii, which were themselves slightly thickened, on

the aortic valve was without change. The coronary arteries showed slight atheroma. There was athero-sclerosis of the aorta. The subendo cardial tissue was fatty, showing irregular yellowish streaks throughout, especially in the outflow tract, in the posterior papillary muscle, and in the free trabeculae. Passing over from the aortic flap of the mitral valve to the lower portion of the pars membranacea septi in a horizontal direction was a strand of dense connective tissue. It will be understood that this structure passed close to the normal site of transit of the *A - V* bundle through the septum.

Microscopic examination of the heart. The heart was fixed in Formol-Müller solution for 36 hours and was then washed in running tap water until clean. It was kept in 70 per cent. alcohol.¹ The usual portion of the inter-auricular and inter-ventricular septum was excised; that is to say, the part included between an incision which runs parallel to the free edges of the aortic cusps, and backward to the posterior edge of the whole septum, and another parallel with this about 2 cm. below the septum membranaceum and of similar extent. These parallel and horizontal incisions were then joined at their anterior and posterior extremities by vertical ones. The septum membranaceum, the two cusps of the aortic valve (anterior and right posterior), the inter-auricular septum and the posterior wall and surface of the right and left auricles were therefore included in the excised piece. Contrary to the method used in a heart previously reported,² the tissue was embedded in its entirety. It was first permitted to lie in thin celloidin for about two weeks, dried rapidly in the air, no excess of celloidin being allowed to remain on the surface, cleared in cedar wood oil, and finally embedded in chloroform and paraffin. The ease in cutting was greatly facilitated by using the vacuum device recommended by W. Henwood Harvey.³ Forty minutes sufficed for the thorough impregnation of this rather large piece of tissue. The block was cut in serial sections, 10 micra thick, and every fifth section mounted. The entire series was stained with Weigert's iron-haematoxylin and Van Gieson's solution.

The sclerosis seen at the post-mortem was again demonstrated microscopically, both in the aorta and in the cusps of the aortic valve. While here and there small areas of round cell infiltration appeared, the entire process might be described as one of replacement sclerosis. The lesion did not appear to be syphilitic. A general increase in the connective tissue was also seen in the small vessels in the posterior portion of the inter-auricular septum, where the adventitia was markedly thickened. There was no endarteritis; the lumina of the vessels was not contracted. The periarteritis also involved the aorta to a slight extent. The nerve bundles and the ganglia which were found in the inter-auricular septum showed an increase in the connective tissue of the neurilemma and of the endoneurium.

There were numerous places in the wall of the right auricle, rather close under the endocardium, where a marked increase in the interstitial connective tissue, with corresponding atrophy of the subjacent intrinsic

cardiac muscle, was noticeable. The process was on the whole a far reaching one, affecting the wall of the auricle at various levels. In other portions there was an ingrowth of strands of fatty tissue between the muscle bundles. Much further down, in the inter-ventricular septum, rather marked fragmentation of the heart muscle had taken place; this lesion is regarded, of course, as a terminal occurrence. Judging from the condition of the transverse striations, there was no parenchymatous degeneration.

Examination of the septum membranaceum revealed a marked increase of the connective tissue at the central fibrous body and in the membranous portion itself, which had undergone hyaline change. Sclerosis, with hyaline degeneration, was indeed the typical lesion of the septum membranaceum, a fact which could be surmised from the gross appearance. The auriculo-ventricular node (Aschoff-Tawara) lay to the right of the central fibrous body. Its general appearance, except for a few dense hyaline connective tissue strands and a moderate amount of fatty infiltration, was normal. Its connection with the auricle was maintained on the right side and dorsally. This junction lay in a bed of fatty tissue. The connection was not so free as is usually the case, though there was no evidence to show that it had been reduced by a pathological lesion. The nodal fibres showed their well-known characteristics; transverse striation was indicated, but much more sparsely than in the muscle of the main stem or in that of the rest of the heart. The small artery usually described as observed in the node made its appearance in the lower portion only.

The main stem of the A - V bundle passed forward in a somewhat oblique direction through the septum to the left. The fibres were well striated. The entire septum membranaceum had, as already noted, an exceedingly dense structure and inroads were made into the bundle by strands of rather dense connective tissue. In addition, and as in the A - V node, there was a moderate fatty infiltration of the substance of the main stem. The main stem was further compromised by the presence of large blood sinuses, which seriously reduced the diameter of the bundle. They were large, thin-walled vessels, cut for the most part so as to appear oval, and had a diameter equal to that of four or five cardiac muscle fibres laid side by side. Their long diameters measured from one and a half to twice the length of the broad diameter. There were a number of them in the course of the main stem. They were not accompanied by inflammatory reaction, and if they originated in an inflammatory process, it was quiescent at the time of death. Their importance lay in the fact that the bundle, including the sinuses, had a normal diameter, and that they occupied a space which reduced the normal tissue content considerably. There was an increase in the amount of connective tissue, not only of the septum itself, but within the bundle.

The right branch arose in the usual fashion and presented but a slight constriction at its origin. A few sections below the level or origin, it attained a greater diameter. *The left branch*, on the other hand, presented abnormalities in its origin and possibly also in its course. At its origin a small bundle became separated from the main stem and passed to the left, to lie directly under the endocardium, just anterior to the central fibrous body. This branch could be followed to the end of the serial sections. This condition, namely, early separation of the fibres from the main stem of the bundle, is comparable to what has been described¹ in the *A - V* bundle in cats and rabbits. The left branch at the point of division of the main stem, showed a marked increase in connective tissue. At its origin, it was almost completely isolated from the main stem by the inroads of this tissue. At one level a continuity between the main stem and left bundle was maintained by a few fibres only. At a lower level the left branch regained its normal dimensions. Conduction from auricle to ventricle in this heart occurred therefore through an attenuated main stem, a very deficient left branch, and an almost intact right branch.

To sum up, the lesions presented by this heart included sclerosis and fatty infiltration of the *A - V* node and main stem together with reduction in size of the main stem by the sinuses described; very marked contraction of the left branch at its origin and some contraction of the right branch. Furthermore, there was an interstitial fibrosis of the auricle and a moderate increase of connective tissue about the nerves and ganglia of the inter-auricular septum.

A. E. C.

III. *Examination of the medulla oblongata and the vagus nerves.*

The medulla oblongata and the caudal two-thirds of the pons Varolii were received for examination, as well as both vagi nerves and their ganglia. After removal from the body they had been placed for 36 hours in Orth's formol-Müller solution and were then transferred to alcohol. As the tissues had been primarily fixed in a chrome salt solution it was not possible to obtain satisfactory Nissl preparations of the nerve cells, while the time they remained in Müller's fluid was not sufficient to permit staining the myeline sheaths by Weigert's method.

The brain-stem was imbedded in celloidin and cut in serial sections at 15 micra in thickness, and every fourth section was stained by hæmatoxylin and van Gieson's picro-fuchsin mixture. The preparations thus obtained were satisfactory and quite sufficient to reveal any definite abnormality that might be present in either cells or fibres.

The vagi and their ganglia were treated in the same manner.

There was no evidence of any gross lesion in the medulla oblongata or pons; neither the scar of an old hæmorrhage or softening, or degeneration

or sclerosis of any of the fibre tracts. The cells of the various nuclei appeared undiminished in number and presented no marked deviation from the normal in their staining reactions. In regard to this, particular attention was paid to the cells of the vagal nuclei; they appeared unaffected. The root fibres, both afferent and efferent, of these nerves seemed also, as far as the methods of examination permitted, unaffected.

The only noteworthy change in that portion of the brain-stem that was examined in serial sections was a considerable arterio-sclerosis of its larger blood vessels, and a slight amount of small round cell infiltration into their adventitial sheaths. This resembled that which is often found associated with cerebral arterio-sclerosis in old persons. These vascular changes were irregularly distributed over the sections and bore no local relation to any of the functional areas of the cross-section of the medulla. They were in no place severe, and, as far as could be seen, had not led to any softening or destruction of the tissue around them. The opinion may be safely expressed that they were not sufficient to produce any serious functional disturbance.

No trace of fibre degeneration could be observed in the extramedullary portions of the vagal nerves, and their ganglia presented no abnormality beyond a considerable deposit of pigment in the nerve cells; but this is notoriously common in these ganglia in persons beyond middle age.

G. M. H.

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CLINICAL OBSERVATIONS ON CONGENITAL HEART DISEASE.*

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IN investigating congenital heart disease, one is confronted with the difficulty of correlating the physical signs with the lesions found after death. With this in mind, it appeared essential that some attempt should be made to reduce certain of the physical signs to a more orderly grouping. Working on these lines, certain more or less well defined types have been isolated, and they are reported in the following pages. At the same time, suggestions are made as to the relationship of these types to certain anatomical conditions which are well known. In all probability, the diagnosis of rare and complex abnormalities in deep seated organs will always be attended with difficulty; but with the accumulation of detailed and grouped physical signs, finally confirmed by post-mortem records, there seems no reason to suppose that it will not be ultimately possible to make a clinical diagnosis of the predominating underlying lesion in many congenital affections of the heart which are compatible with life. The fourteen cases which follow have been examined solely from the clinical standpoint; an attempt is made to show that they fall into two main groups, the first of which may be again subdivided. The physical signs which characterise each group or subdivision are noted, and a possible explanation of these signs is put forward.

A DESCRIPTION OF FOURTEEN CASES OF CONGENITAL HEART DISEASE.

*Group I. Subdivision A.**CASE I. A female, aged 12 years.*

Family History. The father died of pulmonary tuberculosis. The mother was healthy.
Past Illnesses. None.

Symptoms. The symptoms had not been prominent, and had been present for two years only; they had consisted of occasional precordial pain, breathlessness on exertion and palpitation. During the six months prior to examination, pulmonary tuberculosis had become evident.

Physical signs. The patient was florid in type. Cyanosis and clubbing of the fingers were absent.

* Being a portion of a thesis presented and accepted for a doctorate of medicine in the University of Cambridge. The observations were made at the suggestion and under the supervision of Dr. Thomas Lewis.

Cardiac system. The heart's impulse, localized and forcible, was in the 4th space, just internal to the nipple. There was a systolic thrill, faintly perceptible at the apex, which increased in intensity to reach its maximal in the 2nd left space just external to the sternum. It was palpable to the left of the sternum in the whole of the 1st and 2nd spaces in front, and the 3rd space as far as the mid-clavicular line. There was no thrill in the vessels. On percussion* the upper limit of cardiac dulness lay at the 2nd rib, and curved thence to the margins of normal basal dulness. The left limit of cardiac dulness was at the heart's apex beat. The right limit $\frac{1}{4}$ inch external to the sternum. Auscultation at the apex revealed a normal second sound; there was a slight systolic murmur, not conducted outwards, which increased in intensity on being traced upwards. Its position of maximal intensity was in the 2nd space, $\frac{1}{2}$ inch to the left of the sternum. The murmur was harsh in character but not definitely rough. It was audible one inch to the right of the sternum in the 1st and 2nd spaces, in the whole of the 1st and 2nd left interspaces and slightly beyond the mid-clavicular line in the 3rd interspace. It was audible in both carotids and in both interseapular regions behind. The pulmonary second sound was loud, the aortic second sound was accentuated. The pulse was regular and normal. Venous curves showed the *a-c* interval to be of normal length.

Lungs. Signs of pulmonary tuberculosis were present at the left apex and tubercle bacilli were present in the sputum. The other organs were normal.

CASE II. A female, aged 2 years.

Family history. This was traced for three generations; nothing of significance was found.

Past illnesses. None.

Symptoms. This patient came under observation for broncho-pneumonia, prior to which there had been no symptoms.

Physical signs. The patient was florid in type. Cyanosis and clubbing were absent.

Cardiac system. The heart's impulse, rapid and heaving, was in the nipple line of the 5th space. A systolic thrill was present which was similar in character and had a similar distribution to that recorded in *CASE I*. On percussion the upper limit of cardiac dulness lay in the 2nd space; the left limit in the nipple line; the right limit $\frac{1}{2}$ inch to the right of the sternum. On auscultation at the apex, the first sound was normal; the second sound accentuated. A harsh systolic murmur was present, similar in its position of maximal intensity and its area of audibility to that recorded in *CASE I*. It was not audible in the vessels of the neck, nor over the lungs behind. The pulmonary second sound was very loud. The aortic second sound was normal. The remaining systems were normal.

CASE III. A male, aged 7 years.

Family history. There were two other healthy children. The mother was healthy, but one sister had had rheumatic fever, two brothers had had gout. The paternal side was healthy.

Physical signs. Extremé cyanosis was present. Clubbing was not marked. A blood examination showed:—

Red cells	...	10,288,000 per c.mm.
White cells	...	12,000 per c.mm.
Hb. percentage	...	110 per cent.
Colour index	...	.56

Cardiac system. The heart's impulse was in the nipple line of the 5th space. Pulsation was visible in the 4th and 5th spaces. A systolic thrill was present, the limits of which could be accurately mapped out; its palpable area was approximately the same as that noted in *CASES I* and *II*. On percussion the upper limit of cardiac dulness lay in the 2nd space; the left limit $\frac{1}{2}$ inch external to the nipple; the right limit $\frac{3}{4}$ inch to the right of the sternum. On auscultation the first sound was loud and slapping at the apex. The second sound was barely audible. A systolic murmur, similar in character, distribution and point of maximal intensity to those recorded in the preceding cases, was present. The pulmonary second sound was absent, a short diastolic murmur was heard in this region occasionally. The systolic murmur was not heard in the vessels of the neck, nor in the interseapular region. Pulse 120, rapid but regular. The remaining systems were normal.

* The percussion limits were fixed in all cases with the patient in the supine position.

CASE IV. A male, aged 11 years.

Family history. There was a marked family history of cardiac disease and rheumatic fever. The patient's father died of cardiac disease, two paternal aunts had rheumatic fever and cardiac disease, and one died of cardiac failure. The mother had had rheumatic fever and cardiac disease; a maternal uncle had had rheumatic fever. There was also a cardiac history in the preceding generation.

Physical signs. There was a slight tendency to cyanosis, clubbing was absent. Patient was florid in type.

Cardiac system. The heart's impulse, forcible and heaving, was in the 5th space, just internal to the nipple. A systolic thrill, similar in its area of distribution and in its position of maximal intensity, to that noted in the preceding cases, was present. On percussion the upper limit of cardiac dulness lay in the 2nd space; the right limit $\frac{1}{2}$ inch to the right of the sternum; the left limit in the mid-axillary line. On auscultation the second sound was accentuated at the apex. A blowing systolic murmur, maximal at the apex, was audible over the lower precordium; this murmur was conducted outwards to the axilla. A rough systolic murmur was present at the pulmonary base, its position of maximal intensity and the upper limits of the area of audibility were similar to those noted in the preceding cases. It was barely audible in the 4th space and was absent in the 5th space. The pulmonary second sound was markedly accentuated, the aortic second sound was indistinct. No cardiac murmurs were audible in the vessels of the neck, nor in the interscapular region. The pulse was regular, 80 beats per minute. Venous and sphygmograph curves were taken, the *a-c* interval being of normal length. The remaining systems were normal.

CASE V. A female, aged 8 years.

Family history. The patient's mother and a maternal aunt had had rheumatic fever; and the mother suffered from double aortic and double mitral disease.

Past illnesses. Measles.

Symptoms. This patient had suffered from birth from blueness and breathlessness, which usually succeeded any exertion.

Physical Signs. Cyanosis was present, but clubbing of the digits was absent. The patient was florid in type.

Cardiac system. The heart's impulse was of normal character, and lay at the nipple line in the 4th space. A systolic thrill, similar in every respect to that noted in the preceding cases, was present. On percussion the upper limit of cardiac dulness lay at the 2nd rib, and curved thence to the margins of normal basal dulness. The left limit of cardiac dulness lay $\frac{1}{2}$ inch external to the nipple line; the right limit 1 inch external to the sternum. At the apex auscultation revealed an accentuated second sound. There was a blowing systolic murmur, maximal 1 inch internal to the apex, which was conducted outwards to the axilla. On tracing this murmur towards the base, it became fainter, and at the level of the fourth rib, a harsh grating systolic murmur became audible. This murmur was maximal in the middle of the sternum at the level of the 2nd rib cartilage and was equal in pitch all over the aortic and pulmonary cartilages. It was audible over the whole upper half of the chest, in the vessels of the neck and over the lungs behind, being most marked in the right interscapular region. The pulmonary second sound was accentuated. The pulse was 80, and normal in character. Polygraphic tracings showed the *a-c* interval to be normal in length.

Group I. Subdivision B.

CASE VI. A female, aged 8½ years.

Family history. This was traced for three generations. The mother had severe chorea when three months pregnant with this patient, and presented well marked signs of double mitral disease and pulmonary tuberculosis. In the three generations, nine persons (exclusive of this patient and out of a total of thirty-two) had had rheumatic fever or cardiac disease.

Past illnesses. Measles and "pulmonary congestion."

Symptoms. The patient's symptoms had been blueness, slight breathlessness and pain in the left axilla. The blueness dated from birth; it disappeared at times for long intervals.

Physical signs. Cyanosis and clubbing was absent. Patient florid in type.

Cardiac system. The heart's impulse was in the 4th space, one inch external to the nipple line. A systolic thrill was present, the area of which was readily defined and with accuracy. It was confined to the precordium with the exception of a divergence of $1\frac{1}{2}$ inches to the left in the 2nd and 3rd left intercostal spaces. The region of maximal intensity constituted a zone extending from the left 3rd rib to the 4th space immediately external to the sternum. On percussion the upper limit of cardiac dullness lay in the 2nd space; the left limit at the heart's apex beat; the right limit $\frac{1}{2}$ inch to 1 inch to the right of the sternum. On auscultation, a loud harsh systolic murmur was heard. The area of maximal intensity of this murmur coincided with that of the thrills. At the pulmonary cartilage it was very superficial. This murmur was audible all over the chest in front and over the lungs behind; it was more intense on the left than on the right side. It was not audible in the veins of the neck. The apical second sound was loud and harsh. The pulmonary second sound was loud and slapping. The aortic second sound was weak. The pulse was 120, but otherwise normal in character. Polygraphic tracings were taken, and showed the a-c interval to be normal. Well marked signs of pulmonary consolidation were present at the left apex.

CASE VII. A female, aged 6 years.

Family history. Traced for several generations; there was no history of rheumatism, fever or cardiac disease.

Past illnesses. None.

Symptoms. This patient had had no cardiac symptoms, her cardiac symptoms were discovered during the course of a routine examination.

Physical signs. Cyanosis and clubbing were absent. The patient was florid in type.

Cardiac system. The heart's impulse was in the 6th space, $\frac{1}{2}$ inch external to the nipple; pulsation was visible in the 4th, 5th and 6th spaces. A systolic thrill was present, which covered a similar area and had a similar zone of maximal intensity to that found in the preceding case. On percussion the upper limit of cardiac dullness lay at the 3rd rib; the left limit at the heart's apex beat; the right limit $\frac{1}{2}$ inch external to the sternum. On auscultation a systolic murmur was present, similar in character, in its area of audibility in front and behind, and in its zone of maximal intensity to that noted in the preceding case, with the exception that this murmur was audible in the vessels of the neck. The apical second sound was accentuated, while both pulmonary and aortic second sounds were weak. Pulse 80, normal in rhythm and quality. The remaining systems were normal.

Group II.

CASE VIII. A female, aged $3\frac{1}{2}$ years.

Family history. This was traced for three generations. Two cases of rheumatic fever or cardiac lesion occurred. A maternal aunt had rheumatic fever and died of cardiac disease; a maternal uncle died from paralysis, which on investigation of the records of the hospital proved to have been caused by an embolism from mitral stenosis.

Past illnesses. Measles and chicken-pox.

Symptoms. None. She had had "convulsions" at the age of $2\frac{1}{2}$ years and her cardiac condition was discovered during a routine examination at that age.

Physical signs. Cyanosis and clubbing were absent. Patient was pallid and anæmic.

Cardiac system. The heart's impulse was in the 5th space, $\frac{1}{2}$ inch external to the nipple line. On percussion the upper limit of cardiac dullness lay at the 1st rib and curved sharply to the normal dullness at the 3rd rib; the left limit of cardiac dullness lay $\frac{3}{4}$ inch external to the nipple; the right limit 1 inch to the right of the sternum. On auscultation, the first sound was accentuated and the second sound was slightly exaggerated. There was a slight systolic murmur, which increased in intensity on being traced upwards. In the 4th space, the murmur ran right into the second sound. In the 3rd space the murmur was loud and harsh; it started immediately

after the commencement of the systole and ran into a reduplicated second sound, the last half of which faded away into a short diastolic murmur. The position of maximal intensity was at the pulmonary cartilage, where it was continuous. It was a loud harsh murmur which ran through the accentuated second sound, being somewhat reinforced at this instant, and continued as a diastolic murmur. This murmur was audible over the whole of the 1st and 2nd and 3rd left interspaces in front and in the 4th space to a point $\frac{1}{2}$ inch external to the nipple; while it was audible 1 inch to the right of the sternum in the 1st and 2nd spaces. Its area of audibility and position of maximal intensity corresponded closely with those of the systolic murmur in *CASE I*. In tracing the murmur outwards from the pulmonary cartilage, the diastolic element became correspondingly inaudible. It was audible in the vessels of the neck and over the lungs behind. The aortic second sound was normal. The pulse was 100, closely simulating Corrigan's pulse in type; capillary pulsation was not clearly established.

CASE IX. A female, aged 15½ years.

Family history. The family tree was traced for several generations. A maternal sister had had rheumatic fever and a cardiac lesion.

Past illnesses. Measles.

Symptoms. Breathlessness on exertion.

Physical signs. Cyanosis and clubbing were absent. The patient was florid in type.

Cardiac system. The heart's impulse was in the 5th space just internal to the nipple. An early diastolic thrill was present at the apex, which on being traced upwards merged into an almost continuous thrill, maximal at the pulmonary cartilage. This thrill started just after systole commenced and its palpable area was similar to that of the systolic thrill of the preceding case. On percussion the upper limit of cardiac dullness lay in the 1st space; the right limit $\frac{1}{2}$ inch to the right of the sternum; the left limit 1 inch outside the nipple line. On auscultation, the first sound was accentuated at the apex and there was a systolic murmur which was conducted outwards to the axilla. There was a continuous murmur, maximal at the pulmonary base. The area of audibility of this murmur and the conduction character were similar to those of the preceding cases. Only the systolic portion was audible in the vessels of the neck. The aortic second sound was normal. The pulse was 132. Corrigan's pulse and capillary pulsation were present. Polygraphic tracings showed a well marked *pulsus bisferiens*, while the *a-c* interval was normal.

The remaining systems: signs of pulmonary consolidation were present at the left apex.

CASE X. A married woman, aged 38 years.

Family history. One child died of rheumatic fever. The family history could not be traced in detail.

Past illnesses. Uncertain. Rheumatic fever, chorea and scarlet fever were definitely denied.

Symptoms. Precordial pain at intervals for a year only.

Physical signs. Cyanosis and clubbing were absent. The patient was pale.

Cardiac system. The heart's impulse beat was in the 6th space, two inches external to the nipple line. A systolic thrill, similar to that recorded in *CASE VIII*, was present. On percussion the upper limit of cardiac dullness lay at the 2nd rib, and curved markedly outwards to the 3rd rib. The left limit of cardiac dullness lay 6½ inches from the mid-sternal line; the right limit 1 inch to the right of the sternum. On auscultation, a loud continuous murmur was present at the pulmonary cartilage. The murmur was similar to that of the preceding cases. It was maximal at the pulmonary cartilage, and on tracing it outwards, the diastolic portion became correspondingly shorter. At the apex the first sound was accentuated. The aortic second sound was also increased. The pulse was regular and somewhat abrupt. Polygraphic tracings showed the *a-c* interval to be normal.

CASE XI. A male, aged 12 years.

Family history. This could not be traced in detail. No history of rheumatism or cardiac disease could be obtained.

Past illnesses. Measles and chicken pox.

Symptoms. None.

Physical signs. Cyanosis and clubbing were absent. The patient was pallid.

Cardiac system. Pulsation marked in the 2nd to the 6th spaces. The heart's impulse was in the 6th space, 1 inch external to the nipple line. There was a well marked systolic thrill, maximal at the pulmonary cartilage. On percussion the upper limit of cardiac dulness lay at the 2nd rib: the right limit $1\frac{1}{2}$ inches to the right of the sternum: the left limit $\frac{1}{2}$ inch external to the heart's apex beat. On auscultation, the first sound at the apex was accentuated and there was an almost continuous murmur increasing with the systole and failing just before the first sound recommenced. The murmur was maximal at the pulmonary cartilage, where it was loud, harsh and continuous. The conduction of the murmur was similar to the type *CASE VIII*. The systolic portion of the murmur at the apex was conducted outwards towards the axilla. The aortic second sound was normal. The pulse was 96, regular but markedly double. Capillary pulsation was visible. Polygraphic tracings showed a well marked *pulsus bisferiens*, while the a-c interval was normal.

This patient had an abnormal right carotid artery crossing the trachea and visible in the episternal notch.

CASE XII. A married woman, aged 29 years.

Family history. This was traced for a number of generations. One sister, the father, two paternal relations had had either rheumatic fever or cardiac disease.

Past illnesses. Measles, chicken pox, rheumatic fever.

Symptoms. These were very slight. She had occasionally had slight dyspnoea, she had also suffered from hystero-epileptic fits.

Physical signs. The patient had well marked congenital defects in the lobes of the ear on either side, (Fig. 1); an accessory auricle, hard and cartilaginous was present on the cheek

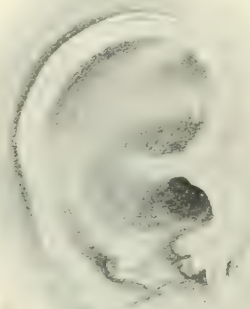


FIG. 1.

midway between the tympanum and the angle of the mouth. There was a congenital dermoid tumour in the conjunctiva at the outer angle of each eye. Cyanosis was absent.

Cardiac system. The heart's impulse was in the 6th space, 6 inches from the sternum. There was a thrill which was maximal at the pulmonary cartilage, which commenced in systole and was continuous. On tracing the thrill outwards the diastolic element became reduced. On percussion the upper limit of cardiac dulness lay in the 2nd space; the left limit 6 inches from the

mid-sternal line; the right limit $\frac{1}{2}$ inch to the right of the sternum. On auscultation, there was a continuous murmur over the whole of the precordium. It was maximal at the pulmonary cartilage. The conduction of the murmur was similar to that in the preceding cases. At the apex the first sound was accentuated. The aortic second sound was normal. The continuous murmur was audible in the vessels of the neck. The pulse was 96; capillary pulsation and Corrigan's pulse were present; polygraphic tracings showed the *a-c* interval to be normal.

CASE XIII. A male, aged 42 years.

Family history. Traced for several generations; no history of rheumatic fever or cardiac disease.

Past illnesses. Measles.

Symptoms. None, his condition being discovered during an attack of appendicitis.

Physical signs. Cardiac system: the heart's impulse was in the 5th space, 4 inches from the middle line. A systolic thrill was present at the pulmonary cartilage. On percussion the upper limit of cardiac dulness lay at the 3rd rib; the left limit at the heart's apex beat; the right limit $\frac{1}{2}$ inch to the right of the sternum. On auscultation there was a soft systolic murmur at the apex, which was conducted outwards to the axilla. The second sound was very weak. There was a continuous murmur at the pulmonary cartilage, the systolic element of which was harsh, the diastolic soft and blowing. Outside this area the murmur was double. The interval between the two parts decreasing towards the pulmonary cartilage. The double murmur was audible in both interscapular regions. The systolic element followed by a clear second sound was alone present in the vessels of the neck. The pulse was 88 normal in rhythm and character. Polygraphic tracings showed the *a-c* interval to be normal.

CASE XIV. A male, aged 20 years.

Family history. Traced for several generations; no history of rheumatic fever or cardiac disease.

Past illnesses. Measles.

Symptoms. Slight precordial pain for three months only before examination.

Physical signs. Cyanosis and clubbing were absent.

Cardiac system. The heart's impulse was in the 5th space, $3\frac{1}{2}$ inches from the mid-sternal line. There was a continuous thrill at the pulmonary cartilage, the systolic element of which was alone palpable and over the usual area. On percussion the upper limit of cardiac dulness lay at the 3rd rib; the left limit at the heart's apex beat; the right limit $1\frac{1}{2}$ inch to the right of the sternum. On auscultation both sounds were accentuated at the apex. There was a continuous murmur at the pulmonary cartilage and it was similar in character and had a corresponding conduction to that of the preceding cases. The aortic second sound was normal. The pulse was 80, and distinctly of the Corrigan type. Capillary pulsation was present; polygraphic tracings showed the *a-c* interval to be normal.

A CLINICAL SUBDIVISION OF CONGENITAL PULMONARY STENOSIS.

Group I. (CASES I-VII, in which the main physical sign was a harsh murmur confined to systole, and maximal in the pulmonary area.)

The past and present symptoms of these patients pointed to cardiac disease. Dyspnoea, precordial pain, palpitation and cyanosis, varying from time to time, were the chief symptoms and they frequently dated from birth. In no case were the symptoms referable to an acute illness. The facial aspect of the cases in this group was uniform, high colouring in the lips, cheeks, and mucous membranes was always present. Cyanosis was observed in three cases only (*III*, *IV* and *V*). Every case showed right-sided enlargement of the heart, though this was more marked in some than others. A systolic thrill was present in all, and in each of these cases it was of maximal intensity at or near the pulmonary cartilage. A rough and loud systolic murmur, also maximal at this point, accompanied the thrill. But while the signs agreed in their main characteristics with a stenosis of a vessel in the neighbourhood of the pulmonary cartilage, so many points of difference were

presented by *CASES VI* and *VII*, that it has seemed possible to effect the following sub-division :—

Sub-group A. (CASES I- V) in which all the physical signs were found relatively high in the chest.

Sub-group B. (CASES VI and VII) in which the physical signs were relatively low in the chest.

Sub-group A. (CASES I- V) In these five cases the position of maximal intensity of the systolic thrill (Fig. 2*a* shaded area) was situated at the pulmonary cartilage and was localized at this spot. The thrill was palpable over a relatively large area of the chest. As will be seen from the upper line of the diagram (Fig. 2*a* dotted line), this area comprised the upper precordium, the left infra-clavicular region as far outward as the line of the anterior axillary fold, and a small region to the right of the sternum in the 1st and 2nd spaces. On auscultation a rough systolic murmur accompanied the thrill. The position of maximum audibility of this murmur was localized at the pulmonary cartilage (Fig. 2*b*, shaded area), and the area of audibility of this murmur in front was approximately that of the palpable area of the thrill (Fig. 2*b*, dotted line). In two cases, *I* and *V*, the murmur was audible in the vessels of the neck, and over the lungs behind, more especially in the left and right interscapular regions. With these exceptions the murmur was not heard in the above mentioned positions, the cardiac first sound being clear. The pulmonary second sound was inaudible in *CASE III*; in the remainder it was accentuated, sometimes to a very marked degree. In two cases, *IV* and *V*, there was an apical systolic murmur, conducted well outwards; with these exceptions the cardiac sounds were normal.

Sub-group B. (CASES VI and VII) In these two cases the area of maximal intensity of the systolic thrill was larger than that occurring in the cases of the preceding sub-division, and extended downwards in a narrow zone along the left border of the sternum (Fig. 3*a*, shaded area), from the pulmonary cartilage to the 4th and 5th interspaces. The area over which the thrill was palpable was limited in extent, it included the whole precordium, and a small region in the 2nd and 3rd left interspaces, external to the precordium (Fig. 3*a*, dotted line). A rough systolic murmur accompanied this thrill, the area of maximal intensity of which coincided with that of the thrill (Fig. 3*b*, shaded area). This murmur, which was very superficial at the pulmonary and 3rd cartilage, was audible over the whole of the chest in front and over the lungs behind, more especially in the left interscapular region (Fig. 3*b*, dotted outline, and 3*c*, shaded area). The pulmonary second sound was markedly accentuated in *CASE VI* and was diminished in *CASE VII*. The only other difference noted in the physical signs of these two cases was that in the latter, the murmur was audible in the vessels of the neck.

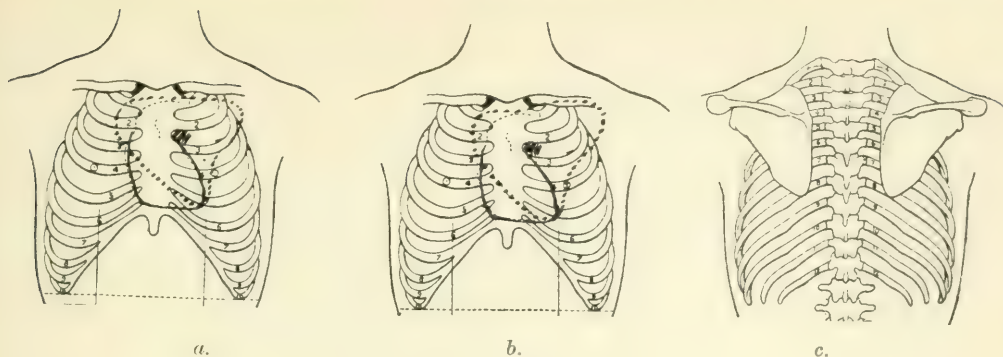


Fig. 2. Group I. A.

- a. The Thrill. Area of maximal intensity shaded, area of palpability dotted.
- b. The Murmur. Area of maximal intensity shaded, area of audibility dotted.
- c. Murmur not audible behind.

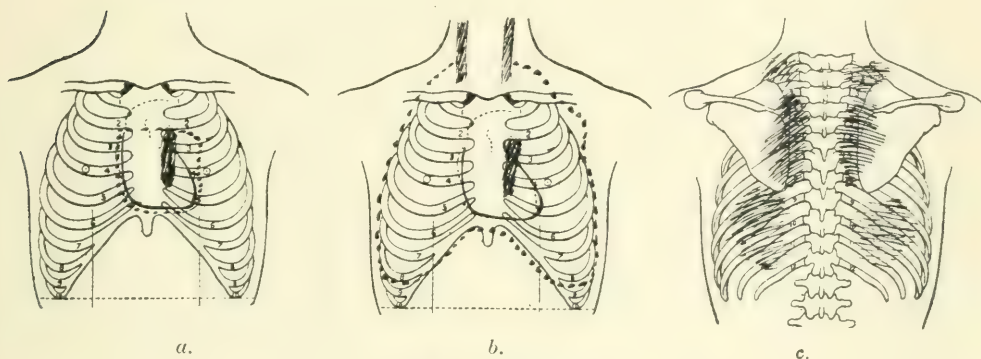


Fig. 3. Group I. B.

- a. The Thrill. Area of maximal intensity shaded, area of palpability dotted.
- b. The Murmur. Area of maximal intensity shaded, area of audibility dotted.
- c. Murmur audible behind over shaded area.

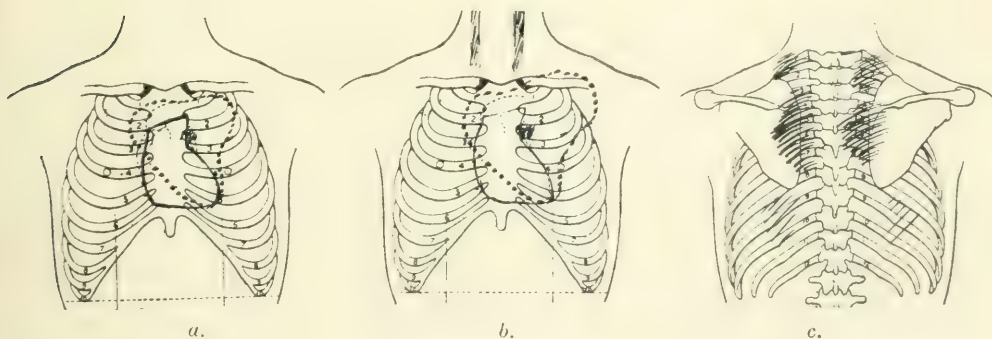


Fig. 4. Group II.

- a. The Thrill. Area of maximal intensity shaded, area of palpability dotted.
- b. The Murmur. Area of maximal intensity shaded, area of audibility dotted.
- c. Murmur audible over shaded area behind.

The points of difference between Sub-group *A* and *B* of Group *I* are as follows :—In group *I, A* the area of maximal intensity of the thrill was localized at the pulmonary cartilage, in group *I, B* it extended downwards from this point along the left of the sternum to the 4th interspace. In group *I, A* the thrill was palpable over the upper half of the left chest in front, in group *I, B* it was not felt above the precordium, and extended lower, so as to include the whole precordium. The area of maximal intensity of the systolic murmur coincided in each case with that of the thrill. In group *I, A* the audibility of the murmur was limited to the left upper half of the chest in front, in group *I, B* the murmur was heard all over the chest in front and behind and in one case in the vessels of the neck.

Group II. (CASES VIII-XIV, in which the main physical sign was a harsh murmur commencing in systole, continuing into diastole, and maximal in the pulmonary area).

The symptoms in this group were often so slight that the condition was discovered only on routine examination. This occurred in *CASES VIII, X, XIII* and *XIV*. In the remainder the symptoms were not severe, dyspnoea on exertion being the most constant. The facies were distinctive, the features being pallid and the lips and mucous membranes anæmic. Cyanosis, or a history of it was absent throughout. On palpitation, a thrill was detected, which in three cases, *IX, XII* and *XIV*, could be definitely ascertained as continuing into diastole; in the remainder the thrill was systolic only. The position of maximal intensity of the thrill was localized at the pulmonary cartilage (Fig. 4*a*, shaded area), and the area of palpability included the upper precordium, a small space to the right of the sternum in the 1st and 2nd interspaces, and the left upper half of the chest below the clavicle (Fig. 4*a*, dotted line). The area of this thrill coincided approximately with that noted in group *I, A*. On percussion the right limit of cardiac dulness was enlarged. A marked feature of this group, only absent in two cases (*XIII* and *XIV*.) was a zonular upward enlargement of the basal cardiac dulness over and slightly to the left of the sternum. This enlargement extended sometimes to the first interspace; it was present, but not to such a marked degree in two cases of group *I* (*I* and *V*). The characteristic physical sign of this group was the additional murmur. A continuous murmur in the pulmonary area was present in every case. It started as a harsh bruit in systole, was reinforced at the commencement of diastole, and becoming softer and less audible, tailed away in diastole, to start again at systole. The position of maximal intensity of the murmur was at the pulmonary cartilage (Fig. 4*b*, shaded area), traced from this point the diastolic element became less audible, so that at the limits of the area of audibility the systolic element was alone heard. The area of audibility of this murmur was fairly constant (Fig. 4*b*, dotted line and 4*c*, shaded area). It included the upper half of the left chest and a small region in the 1st and 2nd right interspaces and was very similar to that noted in group *I, A*,

save that there was a greater tendency for the left supraclavicular and axillary regions to be included. Either as a systolic or as a continuous sound it was audible in the vessels of the neck and over the chest behind, more especially in the left interscapular region. The second pulmonary sound was present at the pulmonary cartilage, it was frequently accentuated and occasionally reduplicated. The second sound at the aortic cartilage was normal with one exception. In three cases, *IX*, *X* and *XIII*, there was an apical murmur conducted outwards to the axilla.

The pulse, with the exception of *CASE XIII*, tended to rise and fall abruptly and in four cases (*IX*, *XI*, *XII* and *XIV*) this was so well marked as to constitute a well marked water-hammer pulse. In the four cases mentioned, capillary pulsation was present. In *CASES XI* and *XIV*, the murmur was increased in intensity by deep inspiration.

The physical signs which group I and II possess in common ; and those which are distinctive of one or other group.

Though the cases comprising group *II* are clearly separable clinically from those of group *I*, certain physical signs are common to both ; while the distinguishing physical signs may be looked upon as additions to those presented by the cases of group *I*. Right sided enlargement of the heart was common to both groups. In all save three cases (*IX*, *XII* and *XIV*) of group *II*, a systolic thrill was present at the pulmonary cartilage. The thrill was very similar both in its position of maximal intensity and in its area of palpability to that observed in group *I*. *A*. In three cases (*IX*, *XII* and *XIV*) the thrill commenced in systole and was continued into diastole at the position of maximal intensity. It was the systolic element of this thrill which was widely conducted over the same area as in the preceding cases.

The main distinguishing features of group *II* as opposed to group *I* were as follows :—

(1). *The notable differences in the history, symptomatology and mode of life.* As has been noted, symptoms in the patients in group *II* were inconspicuous or absent. In the majority of cases, the cardiac malformation in no way precluded the patient from leading an active life ; whereas dyspnoea, sometimes severe in grade, was characteristic of the patients in group *I*. The average age of the patients in group *I* was considerably less than that of those in group *II*, the average being 8 years and 23 years respectively.

(2). *The area, character and duration of the murmur.* The murmur, like that occurring in the cases of group *I* was maximal at the pulmonary cartilage. Though commencing as a harsh bruit in systole, it was prolonged as a softer murmur throughout diastole and was continuous. The conduction, either as a systolic or as a prolonged murmur, into the vessels of the neck and

into a wide area behind was constant. The conduction of this murmur in front and its points of resemblance with the murmur in group *I* have been noted in a preceding paragraph.

(3). *The character of the pulse.* The tendency towards the occurrence of Corrigan's pulse and capillary pulsation was a marked feature in group *II*. These signs occurred in no case of group *I*.

(4). *The increased dulness at the base of the heart.* An increase in the basal cardiac dulness, while occurring in group *I*, notably *CASE V*, was a constant feature in group *II*. This dulness extended upwards in a narrow zone, (Fig. 4*a*) to the level of the first intercostal space. The presence of this abnormal zone of dulness may conceivably be connected with the audibility of the murmur behind.

A table comparing the symptoms and physical signs of Groups I and II.

	GROUP I.	GROUP II.
SYMPTOMS.	RELATIVELY PRONOUNCED.	RELATIVELY SLIGHT.
Facies.	Florid, often cyanosed.	Pallid and anaemic.
Right sided cardiac enlargement.	Present.	Present.
Dulness over the sternum.	Infrequent (present in <i>CASES I</i> and <i>V</i>).	Frequent and pronounced.
Maximal intensity of thrill.	Pulmonary cartilage (systolic)	Pulmonary cartilage (continuous).
Area of palpability.	Group <i>I</i> , <i>A</i> . Upper precordium, left infra clavicular region to anterior axillary fold.	The same (systolic).
Maximal intensity of murmur.	Pulmonary cartilage.	The same (systolic).
Area of audibility of systolic portion of murmur.	Group <i>I</i> , <i>A</i> . Upper precordium, left infra clavicular region to anterior axillary fold.	The same.
Audibility of murmur in vessels of neck.	Group <i>I A</i> : <i>CASES I</i> and <i>IV</i> Group <i>I, B</i> : <i>CASE VII</i> .	Constantly audible.
Audibility behind.	Group <i>I, A</i> : <i>CASES I</i> and <i>VI</i> Group <i>I, B</i> : <i>CASES VI</i> and <i>VII</i> .	Constantly present.
Corrigan's pulse and capillary pulsation.	Absent throughout.	Frequently present.

GENERAL DISCUSSION OF THE POSSIBLE MEANING OF THE PHYSICAL SIGNS.

Group I, A and B. The cases in group *I, A* follow the established description of stenosis of the pulmonary valve with sufficient accuracy to allow such a diagnosis to be made.

From the recognised signs of pulmonary stenosis, the cases comprising group *I, B* are somewhat divergent. Yet there are many features held in common with group *I, A*. The history of the symptoms, the facies and the occurrence of cyanosis may be mentioned. The thrill, systolic in time, was maximal at the pulmonary cartilage, but the area of maximal intensity extended downward to the left of the sternum; while the thrill was palpable only over the precordium. The maximal intensity of the murmur coincided with that of the thrill, but the murmur was audible over the whole chest in front and behind. From a consideration of the points in common between groups *I, A* and *B*, from the situation and area of the zone of maximal intensity of the thrill and murmur, it seems reasonable to suppose that the point of stenosis in group *I, B* is situated, not at the pulmonary valves, but in the infundibulum of the right ventricle. This seems a reasonable explanation of the somewhat large area of maximal intensity of the murmur and thrill in this subdivision, and of the extension of this murmur to, and its superficiality at, the pulmonary cartilage. Anatomical findings make it difficult to conceive that the physical signs of the condition, commonly termed pulmonary stenosis are constant. Greil³ working at the development of mammalian heart, and Keith⁴ working upon malformed human heart, have each brought forward the view that embryologically there is a fourth chamber to the heart. Keith says of this: "The fourth part is the *bulbus cordis*, so well seen in the shark's heart. It is usually supposed that the *bulbus cordis* has disappeared from the mammalian heart, but we have good reason for believing that the *bulbus cordis* has become included in the right ventricle, forming that part loosely termed its infundibulum. A large number of the very commonest malformations of the human heart are due to an arrest of the process which ends in the incorporation of the *bulbus cordis* in the right ventricle. The great majority of cases of congenital stenosis of the pulmonary artery are of this nature." Taking a series of 130 cases of so-called pulmonary stenosis, he effects no fewer than five subdivisions on anatomical grounds. In the 19 cases of his first subdivision, the infundibulum is very large, and the point of stenosis is situated comparatively low in the right ventricle. In the remainder the stenosis is much higher in position, and this alteration of site is regarded by Keith as one of the evidences of absence of, or incomplete expansion of the fourth chamber (the infundibulum). It may be noted that this condition occurred in 14.6 per cent. of Keith's cases of pulmonary stenosis. The incidence in the present collection, assuming the diagnosis to be correct, is 14.3 per cent.

Group II. In the general account of group *II*, it has been shown that these cases were characterised by the same features as those of group *I* up to a certain point, with additions to the physical signs. The added phenomena were the freedom from symptoms, the diastolic portion of the murmur, Corrigan's pulse, capillary pulsation and a constant area of well marked dulness over the manubrium. The continuous murmur was described by Gibson² and clearly shown by him to be the result of patency of the ductus arteriosus. Libman³ and Bommer¹ have also described the murmur as an accompaniment of the same lesion.

The patients in group *II* presented few signs of circulatory disturbance, their symptoms were as a rule slight or altogether absent, and their average age was much greater than that of group *I*. Assuming the presence of pulmonary stenosis, persistency of the ductus arteriosus may be regarded as advantageous to the circulation. When a severe grade of stenosis is present, deficient aeration may be expected, and it is obvious that the patency of the ductus arteriosus will to a great extent overcome and eliminate this difficulty, for pulmonary stenosis is usually associated, as we know, with a patent interventricular septum.

Turning to the anatomical data it is found that patency of the ductus Botalli, unaccompanied by any other lesion, is rare. Keith⁴ mentions that he has found it twice, presumably in his series of 270 cases. The very high proportion of cases presenting continuous murmurs, in this collection of cases (7 out of 14) at once negatives the conclusion that the only lesion was a patent ductus. The frequent combination, pulmonary stenosis and patent ductus arteriosus is emphasised by Peacock,⁵ and the collected anatomical observations of these and other writers harmonises with the view adopted, namely the presence of the double lesion in group *II*.

The occurrence of a water-hammer pulse and capillary pulsation in patent ductus arteriosus cases.

Reference has been made to the occurrence of the above phenomena in group *II*. In the sphygmographic tracings of this group the radial upstroke is abrupt. In these cases, notably, in *CASES IX, XI, XII* and *XIV*, a water-hammer pulse was present on raising the arm, and capillary pulsation was noted. These physical signs, commonly characteristic of aortic regurgitation, are by no means incompatible with the mechanics of the circulation in a case of patent ductus arteriosus; for while in a disease of the aortic valves, there is regurgitation into the ventricle, in patency of the ductus, there is a reflux into the pulmonary artery. As in aortic regurgitation, so in this last condition, the regurgitating blood will be greater in some cases than in others, and this phenomenon may be expected, and judging from the signs is actually found, to show varying grades of prominence from case to case and with different phases of respiration.

The incidence of rheumatic fever and cardiac disease in the family history.

In *CASE I* no reliable details of the family history could be obtained. In nine cases detailed family trees (for three generations wherever possible) were compiled, while in the remainder (*III, V, X and XI*) the family history was traced as fully as the circumstances allowed. Excluding *CASE I*, five cases (*II, VII, XI, XIII and XIV*) showed no tendency for the individual or the family to be infected with rheumatic fever, chorea or cardiac valve lesions. In the remaining eight cases, the occurrence of rheumatic fever and cardiac affections was a feature in the history of the family, and sometimes a very marked one.

CONCLUSIONS.

(1) By a careful examination of the physical signs in patients suffering from congenital morbus cordis, it is probable that, with the accumulation of details, such cases will be divided into clinical groups of distinctive types, and that eventually, when such clinical groups have been established and the morbid conditions associated with them described, the diagnosis of one lesion from the other, and the prognosis based upon it, will be possible.

(2) Exclusive of other lesions, such as septal defects, there appear to be at least three clinical groups of pulmonary stenosis :—

I. A. Cases in which the signs seem to indicate a constriction in the neighbourhood of the pulmonary valves. High stenosis.

II. B. Cases in which the signs seem to indicate a constriction and incomplete fusion of the infundibulum with the body of the right ventricle. Low stenosis.

III. Cases in which there are evidences that the ductus arteriosus is also patent.

(3) Patent ductus arteriosus may give rise to a water-hammer pulse and capillary pulsation.

(4) In many cases of congenital heart disease, and more especially when there is evidence of ductus arteriosus patency, an abnormal zone of basal cardiac dulness is present.

(5) There seems to be evidence that where pulmonary stenosis is accompanied by patency of the ductus arteriosus the symptomatology is less severe and life more prolonged.

(6) A large percentage of cases of congenital heart disease, associated with pulmonary stenosis, give a definite history or family history of rheumatic infection, or a history of cardiac disease in other members of the family.

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A CASE OF ANGINA PECTORIS ASSOCIATED WITH GREAT EXCITABILITY OF THE VASO-CONSTRICTOR MECHANISM.

By JAMES MACKENZIE.

(*London*).

H. E. admitted to Mount Vernon Hospital on July 5th, 1910, was 35 years of age and married.

History. He had been a soldier, and up to three years ago, did heavy work as a labourer, but for the twelve months preceding admission, had been unable to work. The patient had had rheumatic fever at 15, and was then told that his heart was affected. He had had two slight subsequent attacks. Twelve years before he had had a chancre and was treated for 10 days. There had been no secondary manifestations. He had had diphtheria eleven years ago. For the preceding five years, he had been subject to attacks of pain in the chest, of a severe gnawing kind, accompanied by painful gripping of the chest, dyspnoea, faintness, fear, palpitation, throbbing and sometimes nausea. During the attack he perspired freely. The pain passed off very gradually. The attacks occurred frequently, sometimes every hour. They came on even when he lay in bed, and to obtain ease he often slept after an attack, kneeling on a pillow and resting his chest on the edge of the bed.

State on Admission. Examination. When free from pain, the patient usually lay very quietly in bed, avoiding all movement. When he had to move for any purpose, he did so with deliberation, evidently in fear that some untoward act might provoke an attack. When spoken to he replied in a quiet unemotional manner. During the attacks of pain, he resorted to various devices to find an easy position, and was frequently found leaning on a chair, or kneeling by his bedside. His face was pale and drawn, his body fairly well nourished. The rate of the pulse varied between 70 and 90 beats per minute. The radial pulse was large and collapsing. The ulnar artery was also large and there was visible pulsation of the subclavian and carotid arteries. After rubbing the forehead, capillary pulsation was seen. The apex beat of the heart was displaced downwards and to the left, and extended two inches beyond the nipple line. Its area was increased, and it was

thrusting in character. At the aortic area, loud systolic and diastolic murmurs were heard. There was also a murmur, systolic in time but of different character, over the apex.

Site of the pain. The following is the patient's own account of his attacks, checked by observations made during the attacks. He stated that the pain commenced in the region of the lower end of the sternum, spreading across to the left breast, then up the left side of the chest, down the inner side of the upper arm (left) to the ulnar side of the arm and hand. In severe attacks, the pain was left along the left jaw and sometimes also along the right jaw and down the right arm. When the pain was felt along the lower jaw, it was worst opposite two decayed and tender teeth, one in either jaw. When the pain started it rapidly reached its worst. In addition to the pain in the chest there was a sense of pressure, which the patient described as similar to the sensation felt when the manometer bag compressed the arm. After the attack passed off, the throat was tender and there was pain on swallowing for some hours.

Appearance of patient during an attack. The patient was pale and somewhat sallow, but when the attacks came on he became still paler and slightly cyanosed. He breathed deeply and frequently and occasionally held his breath in inspiration. He moved uneasily if lying down, and as the pain increased he got up, preferring to stand, leaning over a chair and pressing his chest firmly against the chair back. Perspiration usually broke out and his forehead became damp. When in bed or leaning over the chair, the shock of each ventricular contraction gave a movement to his trunk and to the bed or chair on which he was resting.

Duration of the attacks. The attacks were often slight and would pass off in a few minutes, but some lasted for a few hours. While suffering from those lasting the longer time, the patient usually changed his position, generally ending by kneeling with his head resting on the bed, in which position he would wait till the attack passed off, spending the remainder of the night asleep in this position.

Frequency of the attacks. The attacks varied in frequency, sometimes he would have as many as twelve in the day, six during the day time and six during the night. At other times they would be less frequent, but there was rarely a day that he did not experience three or four bad attacks.

Causes inducing the attacks. Most of the attacks came on from no apparent cause, thus when lying quietly in bed asleep or awake the attack might come on, and would often be of the most severe kind. Exertion, such as walking, would induce them, and any cause of mental excitement, for

example interrogation or a physical examination, was sufficient to start them. So provocative was this last circumstance, that we desisted from examining him, until the treatment had subdued the attacks.

The pulse and blood pressure. Usually the pulse rate varied from 76 to 90 beats per minute, but during an attack the radial artery became small and contracted and the rate increased to 136 beats per minute, gradually falling as the attack passed off. Coincident with the increase in the pulse rate, there was a rise in the blood pressure. When free from pain, the blood pressure fluctuated from 118 to 138 mm. Hg.. When the attacks came on, and the rate increased, there was a coincident rise in the blood pressure and in the pulse rate, the blood pressure rising in severe attacks as high as 240 mm. Hg., and in one attack over 300 mm. Hg.. As the pain subsided, the blood-pressure fell. During an attack the coincident changes in the pain and blood-pressure occurred whether the subsidence of the attack came about spontaneously or by the use of remedies.

The effects of remedies in an attack. The following account of one attack presents a typical picture of the more salient events, and the effects of remedies. On July 10th, 1910, as we entered the ward, the patient was lying in bed and his blood-pressure was at once taken. He was a little startled and the blood-pressure was found to be 160. He was left alone for a few minutes, while an examination was made of some of the other patients. On returning to his bed, the blood-pressure was still found to be 160. Expecting an attack to supervene, the instrument was kept applied and the pressure taken at intervals of one to two minutes. The pain began in the manner already described, and as it increased in severity the blood-pressure gradually rose to 220, when nitrite of amyl was inhaled. The face became flushed, but relief was not marked until a second capsule of nitrite (each capsule contained 5 minims) was inhaled. The pain ceased and the blood-pressure fell to 154 mm. Hg.. Immediately after the cessation of the inhalation, the pain began to return, slight at first, but gradually becoming more severe. At the same time, the blood-pressure began to rise, till in $3\frac{1}{2}$ minutes, it rose from 164 to 220 mm. Hg.. Chloroform was then administered and rapidly pushed till he was partly unconscious; the same result followed, the blood pressure fell and the pain disappeared. When the chloroform inhalation ceased, the blood-pressure rose and the pain returned. This attack was subsequently relieved by an injection of morphia. The alterations in blood pressure are shown in the accompanying chart, from the records taken during the attack described (Fig. 1). Hypodermic injections of morphia gave relief and the following is an observation typical of the results after $\frac{1}{4}$ grain of morphia.

Dose.	Hour.	Blood pressure.	Pulse rate.	Sensations.
	11.55	172	124	Pain moderate.
Morphine	11.58			
$\frac{1}{4}$ gr.	12.2	188		Pain worse.
	12.7	202	120	Pain severe.
	12.10	184	116	Pain a little better.
	12.15	172	120	Pain still lessening.
	12.30	154	116	Pain same. Patient lying more quietly.
	12.35	164	116	Pain easier, pupils moderately contracted.
	12.40	164	120	Eruptions of gas, which gave relief. "Pain is still there."
	12.55		80	Pain disappeared.

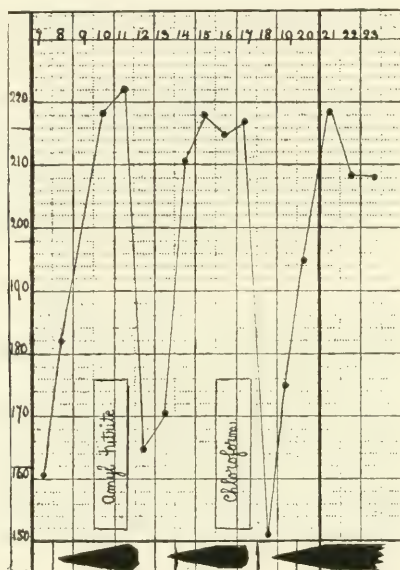


Fig. 1. Chart showing the rise of arterial pressure during an attack of angina pectoris, and the effect of amyl nitrite and chloroform on the pressure. The figures in the left border represent mm. Hg. and the figures on the top represent minutes. The observation began at 11.7 a.m..

The wedge-shaped figures represent the pain, the increase in width representing an increase in pain and the space between the figures a cessation of pain.

Progress and Treatment. It was manifest from the first that the exhaustion of the patient's heart was so extreme that it was vain to expect a restoration of the heart's strength. Moreover he had been under treatment for years, and a few days before being admitted to the Mount Vernon Hospital he had been discharged from a hospital where he had lain for several weeks unrelieved. Various means were employed to give relief during the attacks, while other measures were adopted to prevent their recurrence. For the relief during attacks, all remedies that acted speedily were very transient in their effect, and immediately the patient recovered from their effects, the pain returned, as is shown in the observation of July 10th (Fig. 1). At the suggestion of Professor Cushny, a mixture of nitrous

oxide gas and oxygen were inhaled. This produced a transient loss of consciousness and the pain returned with the return of consciousness. The only remedies that were effective were morphia and chloral, and these had to be pushed until their soporific effects were produced. In searching for the cause of the attacks, we recognised that the nervous system was implicated, as shown by the excitability of the vaso-constrictor mechanism and the readiness with which the pain and rise in blood-pressure were provoked. It was resolved therefore to direct the treatment mainly to the nervous condition, and for this purpose bromide of ammonium was prescribed. On July 11th, the patient was given 20 grains three times a day, and this was continued till the 27th, when the dose was increased to 30 grains thrice daily. No definite effect was detected for the first ten days after beginning the bromide, but then he became slightly drowsy, although the attacks continued to occur. After the dose had been increased, he became more languid and drowsy, and the attacks became greatly modified, becoming much rarer (one to three a day), and so slight that the patient said they were not worth complaining about. He stated further that he had not had such ease for many years as he had for a few days at this time. On August 1st as he was very drowsy and free from attacks, the medicine was stopped, and resumed on the following day in doses of $7\frac{1}{2}$ grains thrice daily. He gradually came out of the stupor and the attacks began to recur, though they were not so frequent as before taking the bromide. On account of the recurrence, the dose was increased on the 5th to 15 grains thrice daily, but this had little effect, the attacks recurring with their old severity. On the 10th, the dose was increased to 30 grains thrice daily and continued till the 18th, when the dose was reduced to 25 grains. During this time, the attacks recurred, but they were not severe. On the 18th the patient became violent and delirious and was soothed only by the administration of morphia or hyoscine. He became weaker, his pulse rate increased to 140, and he became unconscious and died on August 22nd.

A post mortem examination was made, and the heart sent to Professor Woodhead for examination. The following is his report.

Post mortem report. The heart is enormously dilated. Weight 34 oz. On the outer surface, there are the remains of comparatively recently formed fibrous adhesions on the surface of both ventricles, especially on the anterior surface. Length of heart, externally, from base to apex in a straight line, 20.3 cm.; length of ventricular portion, 14 cm.; greatest circumference, 35.6 cm.; left ventricle much dilated. Length of left ventricular cavity from aortic valves to apex, 11.4 cm.; diameter at widest portion, 6 cm.; thickness of wall at thickest part, 2.5 cm., at thinnest part 1.3 cm.. The coronary cusp of the aortic valve is thickened at the margins, firm and considerably retracted. The other cusps are in a similar condition. These retracted cusps could not close the large aortic orifice. There must have been well marked aortic regurgitation.

Right ventricle, like the left, increased in length but not so much dilated. Some pale clot in the right ventricle at base between trabeculae; length of cavity from base to apex, 8.9 cm.; thickness of wall, 0.85 cm. to 0.65 cm. In this ventricle there is a large firm clot, part of it ante-mortem, extending into the pulmonary artery and dividing with the branches of the vessel. The pulmonary valves are apparently normal.

Left auricle much dilated, walls somewhat thickened; the whole of the vessels have been removed, but around the openings of two of the pulmonary veins, there is considerable thickening of the muscular tissue. The auricular appendage contains no clot and is not enlarged. The mitral valve is in a similar condition to the tricuspid, but more thickened, especially at the margins of the cusp; probably slight incompetence from enlargement of the orifice and thickening of the valves, otherwise normal. Orifice admits four fingers fairly easily.

The right auricle is considerably dilated, vessels cut away, auricular appendage contains a little firm clot, but is not enlarged. Between the pectinated bundles the light may be seen shining through the peri- and endocardium, the muscular bundles being very widely separated. The tricuspid valve-margins are slightly thickened. The coronary sinus is very large.

The aorta is somewhat thickened by patches of commencing atheroma. No calcareous degeneration of the somewhat thickened aortic valves.

Coronary artery to the right side somewhat narrow, but otherwise apparently normal. A probe passes along quite easily and there is little thickening of the wall. The left coronary patent and large, perhaps slightly thickened, but not markedly so. Wonderfully little change in these vessels. Just below entrance of left coronary artery is a large calcareous patch at the base of the cusp.

Microscopic examination. (a) Muscle from mid-way between base and apex of wall of enormously hypertrophied left ventricle.

Considerable increase in the number of connective tissue nuclei and of connective tissue fibrils between individual bundles of muscle fibres; apparently also some increase between the larger bundles of muscle fibre. Some of the bundles of muscle fibre are enormously increased in size, as are the individual elements, whilst some, apparently new fibres, appear to be smaller than usual. Transverse striation not so well marked as in normal muscle. Bloodvessels numerous, patent and containing blood.

(b) Muscle from near base of left ventricle.

Here fibrous tissue, especially near endocardial surface, much more markedly increased. Not the same evidence of hypertrophy as lower down, whilst between some of the denser masses of fibrous tissue, the muscle fibres appear to be smaller and granular, indeed to be atrophied. No pigmentation of muscle fibres. Marked vascularity of tissue. On the endocardial surface

there is a very dense layer of fibrous tissue in which a few isolated atrophied muscle fibres may be seen (isolated Purkinje fibres).

(c) Muscle from right auricle just at base of appendix.

Here the bundles of muscle fibres are intersected by very definite bands of fibrous tissue running between the peri- and endo-cardium. There are distinct gaps between the muscle bundles so that there is little tissue other than connective tissue between the endo- and peri-cardium; the muscle, however, is never entirely wanting in these gaps, though there may be only one or two strands.

(d) Superior vena cava.

Considerable thickening of wall due partly to a great increase in the bundles of thin, wavy (muscle?) fibres, partly to very large, somewhat granular muscle bundles and partly to definite fibrous tissues.

Remarks.

There are several features in this case that merit comment. It is well known that attacks of angina pectoris are much more frequent in association with disease of the aortic valves than with any other valvular disease. Among cases of angina, the characteristic features of arterial constriction will be found to be more marked in aortic valvular disease than in any other form of angina. Although I have taken blood-pressure observations in cases of angina pectoris during the attack, no others have been found which showed the features present in this case, i.e. the rise in pressure consistently associated with the recurrence of pain. For instance, the blood-pressure has been taken before and during an attack of angina, and found to be constant at 180 mm. Hg.. The administration of amyl nitrite has reduced the blood pressure and relieved the pain. After the effects of the nitrite have passed off, the blood-pressure has risen to 190 mm. Hg., but without a return of the pain, and this is the more usual experience. We know that the collapsing character of the pulse in aortic regurgitation is not always due to regurgitation of the blood from the aorta into the heart, but it is partly dependent upon a vaso-motor dilatation of the arterioles. It is evident in cases of the nature here recorded, that the centre for vaso-motor constriction is very sensitive to stimulation, and causes the attacks of high blood-pressure, which are concurrent with the symptoms of angina. So far as can be ascertained, it seems that this sudden rise of pressure during the attack is peculiar to aortic cases, especially in the young.

In looking over the notes of cases of angina pectoris associated with aortic valvular disease, it seems probable that this susceptible vaso-constrictor mechanism is at the bottom of the attacks in many cases.

A lady doctor who suffered from aortic disease and violent attacks of angina pectoris, repeatedly took her arm blood-pressure during the attack,

and always found it much higher than when she was free from pain. Douglas Powell² records a case of a man aged 27 years, with aortic valvular disease in whom, during the attacks of angina, the pulse rate quickened and the artery became threadlike, while the bed shook with each beat of the heart. He notes a similar occurrence in another patient, who suffered from aortic valvular disease.

It is to be noted that the situations in which the pain was felt, were those supplied by nerves, whose central ends are in close association with the cardiac nerves. Thus the region of the chest and arm in which the pain is felt is supplied by the upper dorsal and lowest cervical nerves, which arise in the same part of the cord from which the sympathetic nerve supply to the heart comes. The region in the face, over and under the lower jaw, is supplied by the lower divisions of the fifth cranial nerve, and the origin of this nerve in the brain is near the origin of the vagus.

I have pointed out elsewhere¹ that a hyperalgesia of the tissues of the external body wall is in all probability due to an irritable focus in the central nervous system at the origin of the nerves whose peripheral ends are hyperalgesic. When any stimulus reaches this irritable focus pain is produced. This fact is brought out in this case. The stumps of decayed teeth caused pain when pressed upon, and there was always a little tenderness of the gums around the stumps. When the attacks of angina came on, the pain was always worst just where the tenderness persisted when he was free from pain otherwise. It is legitimate to infer that there was a persistent irritation at the central end of the nerves, supplying the gums around the decayed teeth, and that this irritable focus received an additional stimulus with the onset of the angina, resulting in the sensation of greater pain in this particular area.

This case illustrated one feature which is a useful guide in the treatment of angina pectoris. In all cases of angina pectoris, the nervous factor has to be considered. In many people there seems a greater tendency for pain to arise, and when once the way into the central nervous system is opened, attacks of pain are more easily provoked. In such cases, far better results are obtained by diminishing the susceptibility of the nervous system, as by the use of bromides, than by any treatment directed solely to the heart itself. Moreover, in this case the nervous system was implicated not only by the ready susceptibility to pain but by excessive susceptibility of the vaso-motor centre, whereby the constriction of the arteries was readily produced. Towards the lessening of the susceptibility of the centre, the bromides have a beneficial effect. As a matter of experience, in all cases of angina pectoris, arising in the young with aortic valvular disease, the bromides will be found to be of very great service.

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DIGITALIS.

BY JAMES MACKENZIE.

*(From the Cardiac Wards, Mount Vernon Hospital, London).**Introduction.*

SOME preparation of the fox glove plant (*digitalis purpurea*) has had a place in domestic and medical therapy for centuries. It was however a Birmingham physician, Withering,¹⁸ who in 1785 published his "Account of the Foxglove" and recorded the first reliable observations on its medicinal properties. Although he was most impressed with its diuretic properties, and it was to demonstrate this effect that he published his book, yet he also observed and commented upon cases of heart failure, in which digitalis had had a good effect. From the time of Withering's publication we find in the writings of clinicians repeated references to the action of digitalis on the heart. The most striking effect noticed has been the slowing of the heart's rate, and from this observation, digitalis has come to be regarded as a cardiac sedative, ("Ce grand modérateur, cette sorte d'opium de cœur" as Bouilland⁴ describes it), though Alan Burns⁶ had observed its good effects in dilatation of the heart. Its effect in improving the general condition of the patient, and its action on the digestive system were also widely recognised. But until the middle of the last century, the main action of the digitalis, beyond the diuretic effect, was its action in slowing the heart's rate, and so impressed were the profession with this effect, then as they are to-day, that it was used in all sorts of cases where there was an excited or rapid action of the heart. We can now demonstrate that it is chiefly in one class of case that this action is so distinctive, but as this was not formerly recognised, the drug was used indiscriminately, and as it was found ineffective in many cases, digitalis came to be regarded by some as very capricious in its action, while others have attributed the frequent absence of result to the inefficacy of the preparation used.

The view that digitalis is a cardiac sedative led to a restriction of its use. Thus Corrigan⁷ reasoning that because it increased the duration of the diastolic period of the cardiac cycle, assumed it would be a dangerous drug in aortic regurgitation, a view still held by many clinicians.

In the middle of the last century, with the advent of experimental observation on the action of drugs, clinicians began to seek in their patients, results corresponding to those found by the physiologist and experimental pharmacologist. It is from this standpoint that the more recent clinical writers have attempted to describe the action of digitalis, and to a certain extent, these preconceived ideas have influenced their suggestions as to its use and action. Partly on account of the theoretical effects expected from the use of digitalis, and partly on account of the seeming variability in its action, the present day views on the action of digitalis are extremely confusing. Many physicians advocate some special preparation, and there is no agreement as to the most serviceable form in which it may be given. In like manner, the dose and its manner of acting is unsettled. Some maintain that with small doses they get a reaction, while others are equally confident that it is only by larger doses that the effects are produced. Some calculate to find evidence of its effect in a few minutes after its administration; while others maintain that it can act only when the system has received a sufficient quantity, and that it may be several days before even moderate and regular doses can be shown to have any result.

It is now almost invariably held that digitalis causes constriction of the blood vessels, and as such constriction tends to raise the blood pressure, the drug is supposed to be contra-indicated in cases of high blood pressure. This view seems to be based more on theoretical considerations, derived from the results of pharmacological experiments, than on careful observation on the human subject.

It will be realised that there is some need for an investigation into the action of digitalis on the human heart. Till recent years such a thing was not practicable, inasmuch as many of the phenomena produced by digitalis were so obscure in their nature, that when they appeared, their interpretation was not possible. With the recent advances that have been made in the interpretation of the meaning of obscure phenomena, we are now better prepared to observe and record those changes in the circulatory system, which are due to the action of remedies in the ordinary routine of therapeutic practice. We may not be able to solve all the phenomena which are detected but we know sufficient to help us to advance the study of the subject to some extent.

Many years ago I was struck with the variability in the action of digitalis in different patients, and a careful grouping of cases which presented similar effects led me to realise that, to a great extent, the different reactions obtained in different people are due to a difference, not in the drug, but in the nature of the lesion from which the patients suffer. I drew attention to this fact in a paper published in 1904,¹³ and gave more extended observations in a book on diseases of the heart, published in 1908.¹² These observations were made in the course of my routine work in general practice, and lacked the precision and definiteness which can be obtained in hospital practice. When I was appointed to the charge of the cardiac

wards at the Mount Vernon Hospital, I seized the opportunity to study the effects of cardiac remedies in more detail. My previous experience gave me very clear and definite lines to follow, and while engaged in following them, other problems arose, which we attempted to settle; but many of them were beyond our powers, requiring new methods of observation, which we had not the means of employing. The following account of observations is therefore only partial, and though it reveals many new points, and explains much that has hitherto been obscure, it is to be considered merely as the beginning of a series of observations, which need to be carried on by many workers, on a large number of patients and by improved methods. The conclusions drawn from the observations here recorded must be considered as tentative. In order that the reader may recognise the nature of the complaints from which patients suffered who have or have not reacted to digitalis, I have added a sufficiently detailed account of each patient to permit of its recognition.

Methods.

In a previous number of this Journal,¹¹ I gave an account of the methods we employed in the work. These consisted in the close observation of the patient from day to day, noting the character of every symptom, and how it became modified under the influence of treatment. An attempt was made to recognise all the agencies that might possibly modify the effects of the drug. The process of observation was slow and tedious, and the results were only to be obtained by the most painstaking observation of the minutest details. Such simple matters as the recording of pulse and blood pressure needed the most careful attention, as outside circumstances influenced them readily. Certain phenomena, such as irregularities, might occur at rare intervals, and these, to be detected and fully appreciated, needed to be graphically recorded. Graphic records had often to be taken for long periods, sometimes extending to one to two hours, and with great care in order that the nature of the irregularity could be clearly recognised. Certain of the effects of digitalis could only be recognised by observing the response of the heart to effort,—for certain peculiar effects only arose during effort, or when the heart's rate was slowing after effort. As comparatively few of these effects are recorded here, they convey little idea of the amount of work that has been spent in acquiring a knowledge of them, and of the great amount of negative observation which was necessitated.

We have been greatly assisted in our observations by the help and suggestions of Professor Cushny, who associated himself with us in making the observations, assisted us in the interpretations of our results and experimentally tested the relative efficacy of the drugs we used.

The final results could never have been arrived at without the enthusiastic collaboration of my colleagues, Dr. Hume Turnbull, Dr. F. W. Price, Dr. Silberberg and others.

In cases of obscurity and where more precise information was wanted, Dr. Lewis made electrocardiographic observations and interpreted the results for us.

Preparation of the drug and doses employed.

Preparation used. We thought it advisable to limit our observation in the first instance chiefly to one preparation in order to obtain clear and comparable results. In order that our observations might be of practical value to medical men generally, we used the form which is probably the one most frequently prescribed, namely, the B. P. tincture of digitalis. In my earlier observations I had chiefly used the tincture and had always found it efficient: my experience of its service for many years in private practice has been corroborated by the experiences detailed in this article. We tried to estimate the relative value of other preparations: thus, we found that 15 minims of the tincture of digitalis were equal to one granule of Nativelle's digitalin. (which contains $\frac{1}{4}$ milligramme of crystallized digitaline). This conclusion was arrived at by watching for the first sign of a reaction produced by the digitalis, and noting the quantity of the drug which had been taken. From my past experience, I had similarly estimated the relative strength of the well-known pill (containing Pulv. digitalis, Pulv. scillae and Pil. hydrarg. of each one grain) and found that one pill of this combination was approximately equal to 15 minims of the tincture of digitalis. In this instance the constituent squills must be taken into consideration.

Doses used to produce a reaction.

The efficiency of the drug was estimated by prescribing the tincture in a given case in doses of 15 minims or 20 minims, three or four times a day, usually giving the patient one drachm per day and continuing the drug until some definite reaction was obtained. The effects on the kidney, stomach and heart were particularly observed, as it is from one of those organs that the first symptoms usually appear. From the records of cases given, it will be seen that in auricular fibrillation, the slowing of the heart was often distinct before the appearance of any stomach symptom. With the continuance of the drug, nausea appeared, and this was usually the first symptom produced in cases with the normal rhythm. The effect on the rate of the heart was usually slight in cases with the normal rhythm, but the stomach symptoms appeared in cases of auricular fibrillation and normal rhythm with the same or approximately the same total dose. The average quantity which produced nausea in most cases was from five to eight drachms,

when taken in doses of about one drachm per day. In the few cases where doses of two drachms were given per day, the reaction appeared after a smaller quantity was given.

Doses used to maintain a beneficial effect.

In many cases presenting auricular fibrillation the heart reverted to the condition it was in before the drug was given when the effects of the drug passed off. It was therefore deemed advisable to maintain the effects of the digitalis in these cases, and many observations were made to find out the quantity by means of which this object could be attained. Here the data are too scant to allow of broad conclusions. In *CASE 2*, it took 45 minims per day; in *CASE 1*, one drachm per week; in *CASE 12*, one graine of digitalin per day; in *CASES 3, 5 and 7*, it took 30 to 40 minims daily. These were all cases of auricular fibrillation. In the cases with the normal rhythm, the improvement was usually maintained without continuing the drug, unless the patient exhausted his *work force*. This agreed with my experience in private cases; little good was obtained by keeping patients exhibiting the normal rhythm on digitalis, unless sufficient rest was taken. This in a measure also applied to the cases with auricular fibrillation, but in these, the effects of the digitalis were so striking, as in *CASE 1*, as to emphasise the fact that there are factors present in auricular fibrillation which are not present in patients with the normal rhythm.

The method of estimating the necessary quantity was largely left to the patient, with instructions as to the symptoms of a sufficiency, and such patients are generally competent to tell the quantity which acts best: their own sensations are usually the most efficient guide. I have observed the good effects of digitalis taken continuously in small doses when it is required for long periods. One man with auricular fibrillation whom I have had under observation for over ten years made an infusion of digitalis for himself. His guide for its use was the extent of the swelling of his legs. If he could not lace his boots comfortably, he knew it was time to take his digitalis, and in a few days the swelling was diminished and he stopped the drug. *CASE 1* takes an occasional dose when he feels his heart flutter.

Dangerous doses. It is frequently stated in text books that great care should be taken in the administration of digitalis, because of its tendency to produce fatal syncope. Some go so far as to state that a patient taking fair doses of digitalis should be kept in bed, and not even be allowed to get up to micturate. Unfortunately no record of these dangerous cases is given, and seeing that a very large percentage of all patients with heart affections are given digitalis at one time or another, it is not surprising that patients who have been taking digitalis should occasionally die suddenly. As a matter of observation extending over a long period of years, during which my attention

has been especially directed to the action of this drug, I have never seen the slightest danger arise from the taking of digitalis in the doses given here. If the drug is stopped as soon as vomiting or nausea appears, or when the heart's rate falls under 50, I am confident no untoward result will arise.

GENERAL EFFECTS OF DIGITALIS.

The clinician in adopting the ideas and language of the experimental pharmacologist has been misled into a fancied interpretation of the action of this drug, which has little foundation on observed fact. The experimental pharmacologist by his precise methods has done a great deal in revealing the action of digitalis, but the clinician must exercise great judgment in the application of this knowledge in the treatment of his patient, and must himself conduct observations of equal precision.

The striking feature which has appeared as a result of our researches is the dependence of the reaction to the drug upon the nature of the lesion from which the patient suffers. This is a feature which is beyond the ken of the experimentalist, for the hearts he works with are normal hearts, and the reactions of diseased hearts are incapable of experimental reproduction. Moreover, there is another great difference between the experimental and clinical results, in that the experimentalist usually obtains his results in a few hours, and in order to do so has to use doses of a size out of all proportion to that which the clinician, who may not get his results till after several days, can employ.

From these considerations, we have thought it best to make as careful a collection of facts as possible, untrammelled by any preconceived ideas of how digitalis acts, except in so far that some hypothesis might suggest definite lines to follow in the research. This detailed recording of individual cases is all the more necessary, because hitherto the great bulk of clinical observation has been reported in the form of vague generalisations, or as isolated facts, apart from the circumstances which may have given these facts their peculiar character.

The generalisations which follow are not intended as final, but are merely provisional suggestions.

I have been able to separate from the numerous patients to whom I have given digitalis, one group in particular, where the reaction in the heart is so striking, as to enable us to recognise the kind of heart in which a beneficial reaction may be expected. It has been known for a long while that digitalis acts upon certain hearts very speedily, causing great slowing in their rate, and at the same time remarkable improvement in the patient's condition. The class of patient in whom this occurs is limited almost entirely to patients with auricular fibrillation. Occasionally we encounter patients with a normal rhythm, where there is a remarkable slowing of the rate, as in (*CASES 24 and 52*), but these are, in my experience, rare.

As the result of these observations, so far as slowing of the heart's rate is concerned, it may be laid down as a law, that the reaction to digitalis is far less effective when the rhythm is normal than where there is auricular fibrillation. Moreover, when the heart is affected by agents which increase its excitability, the digitalis has little effect upon the rate, whether there is auricular fibrillation or whether the rhythm is normal. This happens for instance in cases with a rise of temperature, when the heart rate is apparently increased only by the temperature and not by the invasion of the heart by a specific organism. Bearing on this point I give brief records of three cases from a series of phthisical patients with a moderate temperature, in which Dr. Evans tried to slow the pulse rate, but though the digitalis was pushed till sickness arose, no slowing of the rate took place. This failure of effect is also evident in conditions where the heart is affected by poisons, whether simple or microbic, as for instance, alcohol, the poisons of infective disease, the specific agent in acute and subacute rheumatism, and the various infective affections of the heart (see *CASE 13*), a modification in the susceptibility to digitalis is also produced by certain changes in the cardiac muscle. At all events, experience shows that reaction to digitalis in auricular fibrillation is much more readily induced in cases with presumably a good deal of healthy heart muscle, than in cases with extensive degeneration of the heart muscle. We find the most striking reaction in the heart of the young, but in the senile heart with auricular fibrillation, we frequently fail to find any reaction, particularly in those without a rheumatic history, and where extensive fibrous degeneration of the heart muscle is found at the post-mortem examination.

Another characteristic reaction is sometimes found in patients with the normal rhythm when the ventricular rhythm becomes irregular, as a result of the stimulus from the auricle failing at times to reach the ventricle (partial heart-block). This reaction I had previously found in a number of cases where there was a delay in the passage of the stimulus from auricle to ventricle, and I was able to anticipate the occurrence of higher grades of heart-block from this circumstance. In one case, which came to autopsy, and where during life there had been a delay in transmission of the stimulus from auricle to ventricle, and where digitalis produced partial heart-block, the *A-V* bundle was found to be damaged. In carefully scrutinising the cases given here where heart-block occurred, (*CASES 17, 18, 21, 24, 27*), there was no evidence of a delay between auricular and ventricular contractions before the digitalis was given.

The action of digitalis as a diuretic is not very evident in the majority of cases given here. Probably this was due to the fact that so few of the patients had dropsy as a symptom. When this was present, it soon disappeared, with the increased flow of urine.

Tolerance to the drug was on the whole very fairly constant. In exceptional cases moderate doses were taken for long periods with no apparent effect, but on the whole the quantity, which when given produced a reaction,

was constant. Nausea was nearly always amongst the first symptoms, and if the drug was pushed, vomiting occurred, accompanied by a feeling of malaise, and often by headache, which was sometimes very distressing. When the drug was stopped, all disagreeable sensations passed off in one or two days, and the patient felt very well.

The improvement in the patient's condition due to the digitalis was most evident in cases of auricular fibrillation. Many of these cases were extremely ill upon admission, and all speedily improved once the digitalis began to act. In cases with the normal rhythm the improvement was not very marked as a rule, and in most of them it is doubtful whether the rest alone was not sufficient to account for the slight improvement.

The maintenance of the improvement is one of the most difficult matters to understand. The improvement in most cases of auricular fibrillation lasted only a few days after the cessation of the drug, and an attempt was made to give the patient just enough of the drug as would maintain the good effect without producing the disagreeable symptoms, and in several cases, (1, 2, 5, 7, 11, 12), this was very successfully accomplished. With the normal rhythm, this tendency to relapse after cessation of the drug was not seen. That improvement under such circumstances is not due solely to slowing of the heart's action can be inferred from a case of heart-block (*CASE 39*), where there was no effect on the pulse rate, but where the improvement was most marked.

Improvement in the patient's condition.

The degrees of heart failure were so varied that it is difficult to represent in any reliable manner the effects of digitalis in restoring the patient's strength. We have attempted to do this in the records of the cases by giving the patient's sensations and noting any evident sign. The terms used to indicate the improvement are not sufficient to express clearly the degree of improvement. They are therefore used with this reservation, that they represent the patient's feelings in comparison with a preceding state, and do not admit of comparison with the feelings of another patient.

To appreciate better the improvement, I will recapitulate briefly the standard I described in the paper dealing with our methods.¹¹ The heart force is looked upon as consisting of a rest force and of a work force. The rest force is that which enables the heart to carry on an efficient circulation when the body is at rest. The work force is that which enables the heart to meet the calls of the body when engaged in effort. Heart failure means, in the first instance an exhaustion of the work force, which may vary in degree, but is shown by a premature exhaustion of the muscle in response to effort. Heart failure is recognised by the patient suffering distress in the performance of some effort he was wont to undertake without distress. When exhaustion of the work force is complete, there is an encroachment

on the rest force, and this impairment of the rest force is manifested by such signs as prostration, general discomfort, or inability to lie flat without distress, or dropsy.

When the patient's state improves, we have to consider the extent of the exhaustion, and the extent to which improvement is possible with a heart affected by lesions which mar its efficiency; and it is at once evident that it is hopeless to expect a recovery of the strength exhibited by a healthy heart. It follows that only a limited amount of force can be regained by the heart, in some cases so limited an amount that there is little or none to spare for work, and hence the patient's heart is able to maintain an efficient circulation only so long as the body is under most favourable conditions. The description of the patients' sensations, given in the record of cases, refers therefore only to his feelings when at rest or after a very limited amount of effort. The amount of restoration of the work force varies greatly, but I have not found a standard of sufficient accuracy with which it may be compared.

In most cases of auricular fibrillation, the condition on admission was such that the rest force was manifestly exhausted, for when in bed, the breathing was laboured, and the patients had to be propped up. In nearly all those instances, where a sufficiency of the drug was taken, the effects of digitalis were extremely good. All the patients were able to lie flat, and were freed from distress of breathing and the sense of discomfort. Some never improved beyond this stage, the effort of standing and walking at once exhausting the heart's strength. In others the improvement, though slow, was steady and ultimately such an amount of work force was acquired, that strenuous work was afterwards undertaken.

One patient (*CASE 1*) was able to keep at his work by judicious continuance of small doses of digitalis. *CASE 7* improved much more slowly, being eleven months under treatment, but when discharged he had acquired a sufficient amount of work force as to enable him to undertake light employment. *CASE 6* recovered so far as to be able to resume his work as a waiter.

In most cases exhibiting the normal rhythm the heart failure was not so extreme, and the improvement was not so marked, the rest force not being exhausted, or only very slightly so, after a few days' rest the patients were free from pain and discomfort, the only sign of exhaustion being produced by efforts such as walking upstairs. Moreover it is doubtful how far the digitalis helped to restore them to the limited recovery which they attained. Before admission they had been exhausting their work force day by day and they only needed a period of rest to permit of a reserve being stored.

In such patients as *CASE 27*, the digitalis undoubtedly had a good effect, even though there were few objective signs of improvement. When under the influence of digitalis to such an extent that he had partial heart-block, this patient felt remarkably well and was able to go about and up

a flight of stairs without distress. It is to be noted that this improvement was not coincident with the actual slowing of the auricular rate, although on account of the heart-block, the ventricular rate was slow and irregular.

Though death suddenly occurred in *CASE 28*, he temporarily experienced great improvement, with no change in the heart's rate.

Effect on the digestive tract.

In practically all the cases of normal rhythm, the first symptom was loss of appetite accompanied by nausea. If the drug was continued, vomiting was induced as a rule. This also happened in cases of auricular fibrillation, but a slowing of the heart generally preceded the stomach symptoms; in two cases (*14* and *15*) the slowing occurred on the same day as the vomiting. Accompanying the nausea, there was a feeling of malaise, the patient feeling extremely unwell. A headache was frequently present, and was sometimes very severe. In no case did the digitalis cause diarrhœa, although in my former experiences, diarrhœa was occasionally provoked. With the other drugs of this group, strophanthus and squills, diarrhœa was more readily provoked. The same symptom has also been noted as a result of helleborein administration.

With the cessation of the drugging the stomach symptoms speedily passed away. In no case was there persistent vomiting, as is sometimes described. With the disappearance of the stomach symptoms, the patient quickly recovered his sense of well-being, sometimes feeling particularly bright and well a day or two after the drug had been stopped. As a rule, there was little difficulty in avoiding the disagreeable stomach sensations, when in cases of auricular fibrillation the circulatory effects could be maintained by the influence of smaller doses.

Effect on the nervous system.

The most frequent nervous symptom was headache. Sometimes it was very severe, and in *CASE 7* it prevented the continuance of the drug for a long time, though it was having a good effect upon the heart. The association of headache, nausea, and the feeling of malaise was fairly frequent, (*CASES 1, 2, 3, 7, 8, 9, 10, 13, 17, 20, 21, 22, 23, 24, etc.*). In a case of paroxysmal tachycardia (not included in the series), the digitalis seemed to have an effect upon attacks of migraine, rendering them much more severe.

In several cases that have come under my care there have been curious cerebral attacks, while the patient was under the influence of the digitalis, and I venture the supposition that they were the result of digitalis. A young woman (pregnant) who was taking digitalis, and in whom partial heart-block was present, was seized with an attack resembling ambulatory

epilepsy. She was busy with her household duties one morning, and she lost all knowledge of her surroundings until she recovered consciousness and found herself sitting by her sister's fireside, about a mile from her own home, weeping. *CASE 3* lost her memory for a few hours, and *CASES 12* and *39* became aphasic for several hours, while under the influence of digitalis. *CASE 38* lost his memory and talked incoherently for a couple of days, while under the influence of digitalis. All these cases completely recovered, and there were no after effects.

Effect on the urinary flow.

In the records of the quantities of urine excreted, there is a striking variation in the quantity from day to day, while the patient was on no drug. Great care was taken to make these records reliable. A study of the tables shows that it was only in exceptional cases that (as *CASES 2, 8, 27, 28*), there was a marked increase in the flow of urine and, with the exception of *CASE 8*, these showed signs of renal inefficiency by the presence of dropsy. It is possible that the urine increased in some instances, but the fluctuation when without digitalis was so great that a definite conclusion cannot be drawn.

The cases showing an increased discharge of urine are too few to allow any definite conclusions to be drawn with certainty, and many more cases must be observed. However it is of interest to note that when the rhythm is normal the increased flow occurs without any definite alteration in the heart's rate.

In *CASE 27*, a patient in whom the normal rhythm was present, the increase in the flow of urine began after he had taken one to two drachms with no perceptible change in the heart's action. There was a distinct relief from suffering, with the onset of the increased flow of urine. In *CASE 28* (normal rhythm) there was a slight increase in the flow after two to three drachms had been taken, and a very marked increase after four drachms had been taken. Here also the change occurred with no simultaneous decrease in the pulse rate or remarkable improvement in the patient's condition. In *CASE 2* (auricular fibrillation) a slight increase in the flow of the urine occurred after five drachms of the tincture had been taken and after the pulse rate had fallen. In *CASE 8* (auricular fibrillation) there was a slight increase the day after he started the digitalis, but the most marked increase occurred after he had taken about 6 drachms, and was coincident with the great decrease in the heart's rate.

Blood pressure.

In taking observations of blood pressure, the systolic pressure was alone recorded. We found that no result of sufficient accuracy could be obtained when the pulse was continuously irregular, the beats varying so much in strength. We therefore gave up the attempt to register the blood pressure

in cases of auricular fibrillation, for though some sort of result could be obtained, the result would be expressed by a figure, and this would have given an aspect of precision, which it did not possess, and would therefore inevitably mislead. We confined our observations on blood pressure to patients with a regular heart action, or in patients with occasional irregularity, in whom there were regular periods of sufficient length for an observation to be taken. As a slight difference in the results obtained by different individuals was noticed, observations in any given case were taken as a rule by the same individual, and always by one of ourselves; observations by the nursing staff were found to be unreliable. The accuracy of our observations was repeatedly tested by compressing the arm and obliterating the pulse, while the radial pulse was graphically recorded, and observing when the lever moved on the return of the pulse while the arm bag was being deflated. We also made numerous confirmatory observations by Korotkoff's auscultatory method. Many of the records are not as complete as they might have been, but such as they are they show that a usual conception of the effects of digitalis on blood pressure is not justified. As a result of experimental observation, it has been assumed that digitalis causes arterial constriction, and in consequence, a rise in blood pressure. But in our observations, even when the drug was pushed and caused nausea and heart irregularities, we could detect no appreciable effect upon the blood pressure, except in *CASE 28*. Some observers believe themselves able to recognise changes in the arterial wall due to digitalis, by means of the finger, but we failed to detect any change. Our conclusions, so far, are that medicinal doses of digitalis do not affect the arterial walls, or if they do so, their effect is so slight as not to be recognisable.

RELATION TO DIFFERENT CARDIAC MECHANISMS.

Auricular fibrillation.

I have already stated that in order to appreciate the results arising from the administration of digitalis in the human subject, it is necessary to recognise the nature of the ailment from which the patient is suffering, and more particularly the lesion affecting the heart. It is in cases of auricular fibrillation that we find that digitalis has the most powerful effect upon the heart.

Symptoms of auricular fibrillation. The clinical signs by which we recognise auricular fibrillation are the following:—(1) The rhythm of the heart in the great majority of cases is continuously irregular. This irregularity is of a disorderly character, (see Fig. 3, 15, 18). Exceptions are found in certain cases of slow action of the ventricles, arising either spontaneously or from digitalis, where the irregularity is only very slight. (*CASES 1 and 3*). (2) All signs of the normal auricular contraction

disappear ; (a) In mitral stenosis with auricular fibrillation, the presystolic murmur attributed to the auricular systole disappears. In many of these cases there is a diastolic murmur resulting from the stenosis of the mitral orifice. This murmur persists, for it is not due to the auricular systole, but to the inrush of blood from auricle to ventricle at the end of ventricular systole. (b) The absence of auricular contraction is best shown in the graphic records. The ventricular form of the jugular pulse with irregular heart action, is proof of the presence of fibrillation in the vast majority of cases. (3) In jugular tracings a series of small oscillations in the veins between the ventricular systoles (Fig. 4, 21, 48) may appear, and these are characteristic of auricular fibrillation. Sometimes these waves are of a fair size, and one falling before the *c* wave may simulate a normal auricular wave. Finally an electrocardiogram of a heart with auricular fibrillation shows no sign of the normal auricular systole, but only the small waves peculiar to the fibrillating auricle (Fig. 53, 54 and 55). For fuller evidences of fibrillation of the auricle, see Lewis's article in this journal.⁹

Comparisons of the effects of digitalis in cases with the normal rhythm and in cases with fibrillation. In a series of observations which I conducted, and which extended over many years, practically all the cases in which marked slowing of the pulse occurred were cases of "*Nodal Rhythm*," as I then termed auricular fibrillation. When one reads critically the accounts of cases in which marked slowing of the pulse has been noticed, from the days of Withering to those of quite recent date, we can infer with fair certainty that these striking diminutions in rate occurred in cases of auricular fibrillation. The records usually state that "the pulse was rapid and irregular," and this, taken with the account of the extreme state of heart failure, is in my experience typical of cases of auricular fibrillation. In the few instances where graphic records have been given to illustrate the slowing of the rate due to drugs of the digitalis group, they all show the characteristic irregularity of auricular fibrillation, (Binz,³ Morison,¹⁵ Hay,⁸ Bailey¹).

Amongst the cases under our care in the Mount Vernon hospital, the majority which showed evidence of extreme heart failure, accompanied by orthopnoea, dropsy and rapid heart action, were cases of auricular fibrillation ; and it was in these cases alone that we obtained remarkable alterations in the heart's rate in response to digitalis. In cases where the rhythm was normal and regular, there was only a slight reduction in the rate in the great majority of cases. In only two cases with the normal rhythm was there marked slowing (*CASES 24 and 25*), and it will be seen that the rate was a moderate one before the administration of digitalis. In cases with apparently similar valve lesions, the difference between those with the normal rhythm and auricular fibrillation is very striking. In order to bring this out clearly, I have taken a series of patients with auricular fibrillation and stenosis of the mitral valve, and have grouped their pulse rates for ten days.

beginning with the day on which digitalis was first administered. I have divided each daily total by the number of patients, and have charted the results (Fig. 1, with solid dots). I have taken an equal number of patients with mitral stenosis, but where the rhythm was normal, the auricle preceding the ventricle in the normal manner, and I have charted the results in the same way. These are shown by the thin line with circles in Fig. 1. It will be seen that there is a very marked difference in the reaction of the two groups.

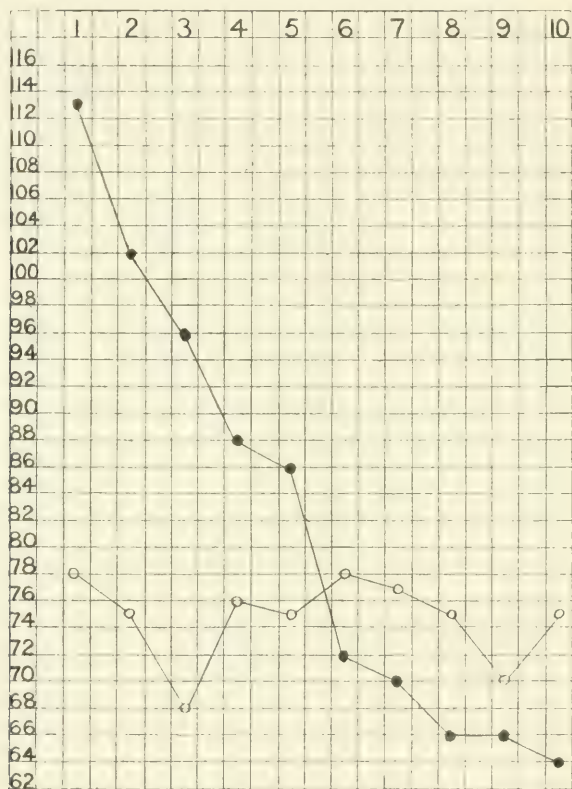


Fig. 1. Chart comparing the effect of digitalis in cases having auricular fibrillation and with those having a normal rhythm. The black dots represent the rate with auricular fibrillation and the white with the normal rhythm. The side figures represent pulse beats, the top figures represent days.

In the one group the fall in rate is speedy and continuous, in the other the effect is very slight. In both groups the digitalis was pushed until there were gastric disturbances, and in both groups the quantity producing this gastric disturbance was practically the same. Before the administration of the digitalis the patients in the first group were all very ill, some of them in great suffering, those in the second group were not so distressed. The records of these cases are given, those of the first group being the patients described in *CASES 1 to 6*, and those of the second group, *CASES 18 to 23*. It

is not for a moment intended that this representation should be taken as correct in every particular, but it will be found to be broadly true and to prevail so widely that we are justified in concluding that, in their reaction to digitalis, auricular fibrillation cases are apart from all others as a class.

This view has been strengthened in the study of other cases which have been observed. In *CASE 17* for instance, where there was mitral stenosis, the rhythm was normal while under observation, except for four days when she had auricular fibrillation, provoked in all probability by the digitalis. In the chart (Fig. 29) her pulse rate is shown on two occasions when digitalis was given until nausea appeared. During the first period there was no effect on the pulse rate, which varied between 72 and 94 beats per minute. During the second period the rate continued unaffected for seven days, when it suddenly fell to 56 beats per minute. The heart at the same time became irregular in its rhythm, the auricular wave disappeared from the jugular pulse and the tracing from the neck showed the features characteristic of auricular fibrillation (Fig. 27). The presystolic murmur disappeared. Suddenly on the fourth day of this abnormal action, when I was examining her, the normal rhythm was restored and at once the rate became greatly increased, the rhythm became regular and the presystolic murmur reappeared. There can be little doubt that the difference in the rates was due to the powerful action of digitalis on the heart during auricular fibrillation, and that the heart is far less sensitive to the action of digitalis when its contraction begins with the normal action of the auricle.

Elsewhere I have recorded a similar experience,¹² where auricular fibrillation seemed to be induced by digitalis, and the rate was slow. On stopping the digitalis the heart reverted to the normal rhythm, but a few months later the auricular fibrillation returned, when the patient was not under the influence of digitalis and the rate was rapid.

Cases of auricular fibrillation unaffected by digitalis. There are cases of auricular fibrillation in which the action of digitalis has little or no appreciable effect. In cases where fibrillation comes on in patients suffering from the degenerative changes of later middle life or accompanying advanced years, digitalis is often without effect upon the heart's rate. I have pushed digitalis in such cases until digestive disturbances were induced (sickness and diarrhoea), but without effect upon the heart. Among the cases given here, we had only one such senile case, and in him there was only slight heart failure. There was only a temporary slowing of the heart for one day while he was nauseated by the drug (*CASE 15*). *CASE 14* showed a similar limited response to digitalis. In febrile cases with fibrillation or where there is a persistence of some toxic affection, digitalis is often without effect; one case of this kind is recorded here (*CASE 13*).

Cases of auricular fibrillation susceptible to digitalis. The cases in which the reaction is most frequent are those with a history of rheumatism. As

a rule the reaction is best seen in the young with fibrillation, but we have had very good results even in the elderly. Fibrillation arising with no previous history of rheumatism can be shown to react markedly to digitalis (*CASES 6 and 11*).

The character of the slowing varies. In *CASES 1 and 3* the heart became more regular in its action, in the former when the rate was between 40 and 50, in the latter when it was more rapid. In a few cases (*3, 5 and 9*), there was a tendency for the ventricle to beat in coupled fashion, occasionally with three beats linked together. As a rule the slowing of the heart rate was accompanied by no marked diminution of the disorderly character of the rhythm.

Coupled beats. The case of coupled beats is of interest, for this reaction has long been recognised though the class of case to which it is limited has not been recognised. In rare cases with a normal rhythm, extrasystoles occur regularly, alternating with a normal beat. In auricular fibrillation there is no longer a dominant sinus rhythm and the ventricular rhythm is disorderly before the onset of the coupled beats. Before the coupled beats appear each ventricular beat usually gives an electrocardiogram characteristic of the normal ventricular contraction. When the coupled beats occur, Lewis has pointed out that the second and smaller beat is of anomalous form and that it arises from some part of the ventricle (see Fig. 54). The rhythm during the period of coupled beats is not quite regular, the interval between the first beats of the couples continually varies, though at times it may vary little. When the coupled beats set in the rate of the pulse alters. If the normal beats are alone counted, the rate falls at once to nearly half, though not quite. If the normal and premature beats are counted, then the rate is increased. Thus in *CASE 5*, just before the onset of a period of coupled beats, the rate was usually 65, and with the onset of the coupled beats, the rate was 70.

Cases peculiarly susceptible to digitalis. There are some cases with a peculiarity in their reaction to digitalis which separates them from all others. Thus in *CASE 5*, a girl aged 17, the susceptibility to digitalis was very marked. When the digitalis was stopped, she always relapsed, in a few days the pulse rate increased and the distress in breathing became so great that she had to sit up in bed, and she looked extremely ill. In a few days the exhibition of the digitalis quite restored her, so that she could lie in bed with comfort, and even get up and walk for short distances. The improvement always occurred when the ventricle took on the coupled rhythm. The peculiarity in this case was that when the heart became rapid in its rate, when it had escaped from the digitalis, it sometimes became quite regular. At the time this happened, the breathing was so distressed that we could not get a tracing of the jugular pulse, but when the rate of the heart slowed it was always found to be of the ventricular form. While I have seen

numerous patients with this tendency to coupled beats I have only seen two other cases which showed such peculiar susceptibility to digitalis and such a marked tendency to coupled beats, with the heart becoming regular when it escaped from the influence of the digitalis. These two cases were also in the young, a boy aged 12 and a girl aged 16, and in both there was a ventricular venous pulse during the irregular rhythm of the heart. I have reported these cases elsewhere^{13, 14}.

It is to be noted that *CASE 3*, which showed a tendency at times to coupled beats was also very much better when she was under the influence of digitalis.

Symptoms associated with the action of digitalis in auricular fibrillation. In many cases one of the most marked features accompanying the reaction of the heart was the great improvement in the patient's condition, and the great relief from distressed breathing and from the general sense of discomfort. In many cases there was a good deal of discomfort for a day or two while the patient was nauseated, but with the stopping of the digitalis the nausea ceased and the patient felt remarkably well.

Other changes were observed in some cases, the face became less blue and oedema of the lungs and legs disappeared. The flow of urine was only increased in those in whom there was dropsy. I had hoped that by careful examination of the heart, we should have been able to detect coincident changes in the size of the heart, but these were so slight in most cases that we failed to get any definite results from our examination.

As a rule the good effect on the general condition only lasted while the heart was under the influence of digitalis, and as the heart escaped, it increased in rate and the field of response to effort became more and more restricted. By giving the digitalis in quantities which kept the heart rate within certain limits (under 70), the patients remained quite comfortable and in some instances they could undertake work entailing a good deal of exertion (*CASE 1*).

Inception of auricular fibrillation under digitalis. *CASE 17*, has already been commented upon; while taking digitalis, the heart suddenly became slower in rate and irregular in its action. The digitalis was stopped and the abnormal action persisted for four days, when suddenly the heart increased in rate and became quite regular. I have also referred to another case where a similar observation was made.

The explanation of the sudden change in the heart's rhythm is that the auricle had fibrillated for these four days. There are many cases where this fibrillation is but temporary, and Lewis⁹ has examined such cases by means of the electrocardiograph, and confirmed the clinical diagnosis by demonstrating that the auricle was fibrillating.

In two cases where there was a long period of tachycardia, due probably to the heart's contraction starting at some abnormal place, digitalis care-

fully pushed induced auricular fibrillation, which lasted for a few days. When it ceased, the heart's contraction resumed its abnormal action in the first instance, and on again pushing the digitalis till auricular fibrillation occurred, the normal action supervened. These cases are briefly recorded here, but will be published later with fuller details (*CASES 37 and 38*). Dr. T. Thompson tells me he has recently observed a similar reaction to digitalis in a case of tachycardia.

Action of digitalis on the rate and rhythm in cases with the normal rhythm.

In cases where there was some cardiac defect, various changes were detected. It may be repeated that in order to detect any alteration in the rhythm, it is necessary to observe the patient after exertion, for when the heart's rate begins to decrease variations in rate and rhythm may arise. When under the influence of digitalis, the sinus irregularity is the most common type. During the slow phases of this irregular rhythm, extrasystoles are apt to appear, and the *As-V's* interval tends to increase, so that beats may drop out as a result of partial heart-block. In some cases all these irregularities appear when the patient is at rest. Among patients with aortic valvular disease, no decrease in the rate occurs. This is of some importance in view of the opinion expressed by Corrigan⁷ and held by many clinicians to-day, that digitalis is a dangerous drug in aortic regurgitation. Corrigan's opinion was based seemingly on theoretical grounds. Accepting the view that digitalis slowed the heart's rate by prolonging the diastolic period he assumed that this increase in the length of the diastole would increase the time during which the blood would flow back from the aorta. Balfour² and others have combated this idea, maintaining that to get the good effects it is not necessary to slow the rate so such an extent as to produce dangerous symptoms, and Balfour quotes a case where good effects were obtained in aortic regurgitation from digitalis, where there was dropsy and dyspnoea. While there is no doubt that digitalis relieves distress of breathing and reduces dropsy, it does not necessarily do so by slowing the pulse. The rate of the heart in cases of aortic regurgitation, with the normal rhythm, is not affected or very slightly in my experience, and *CASES 27 to 36* bear this out.

The effect of digitalis in producing heart irregularities.

In patients with the normal rhythm, digitalis has induced irregularities of the heart's action of the following forms:—(1) Sinus irregularities, (2) extrasystoles, (3) partial heart-block, (4) *pulsus alternans*.

(1) *Sinus irregularities*. These occurred in a number of cases. They were best shown when the heart was slowing after exertion. All the chambers of the heart take part in this form of irregularity, and in this it resembles the irregularity so frequently found in healthy young people (youthful type

of irregularity), but with this difference, that in the youthful form, the irregularity is very often respiratory in rhythm, an increase in the heart's rate occurs during inspiration and a slowing during expiration. The sinus irregularity from digitalis usually occurs in phases of variable duration, but has no relation to the respiratory movement.

These phasic variations are of interest because, during the slow periods, other forms of irregularity tend to appear, for example extrasystoles and partial heart-block. These phasic variations with peculiar irregularities in the action of the auricles and ventricles have been carefully studied by Lewis.¹⁰ In a case recorded by him he showed that the intervals between the auricular contractions may be so long that the ventricles occasionally contract in response to intrinsic impulses. I have recorded elsewhere¹³ a somewhat similar observation in a patient under the influence of digitalis. In these cases it is to be noted there was a serious lesion of the heart's muscle and the *A-V* bundle was undoubtedly affected. The patient whom Lewis observed ultimately came under our care, and the results obtained by Lewis were again observed while the patient was under the influence of digitalis. The patient ultimately died from pneumonia, and in addition to marked changes in the mitral valve (stenosis) there were changes in the myocardium and in the *A-V* bundle. A similar reaction was detected in *CASE 18*, and is commented upon in the paragraph dealing with heart-block.

(2) *Extrasystoles*. Extrasystoles may be provoked by so many influences that in susceptible cases it might be inferred that digitalis would provoke them also. I had previously observed a few patients in whom digitalis readily provoked extrasystoles, but the cases described here only showed them when there was slowing after an increase of rate from exercise. These extrasystoles were always of ventricular origin, sometimes only occasional, at other times alternating with a normal beat (Fig. 46). An electrocardiogram showed that the extrasystole arose from a stimulus within the ventricle, and to be of the same nature as the premature beat in the coupled beats of auricular fibrillation.

CASES 18 and *33* showed extrasystoles on admission, but they disappeared with the rest. On the other hand *CASES 20, 30* and *34*, showed extrasystoles but they persisted in spite of rest. Digitalis had no effect even in diminishing their frequency.

(3) *Pulsus alternans*. In my experience the *pulsus alternans* is produced by digitalis but rarely, and amongst our cases only one (*CASE 27*) showed a tendency to it (Fig. 40). I have elsewhere recorded two cases.¹³ *CASE 23* had well marked *pulsus alternans* on admission but with rest it gradually disappeared as she improved. The digitalis seemed not to affect it.

Fig. 40 shows these different forms of irregularity as a result of digitalis, namely, heart-block, extrasystoles, and *pulsus alternans*.

(4) *Effect on the conductivity of the auriculo-ventricular bundle.* Digitalis may act on the auriculo-ventricular bundle by increasing the interval between the auricular and ventricular systoles, and may prevent the stimulus from the auricle reaching the ventricle (partial heart-block). When this latter event happens, an irregular pulse of a distinctive type is produced. We find in the literature occasional references to irregularities being produced by digitalis, and there is little doubt that many of them were due to partial heart-block. Unfortunately until recent years, graphic records of the irregularities produced were rarely published, and no certain conclusion can be drawn from the verbal descriptions. In one instance which has been frequently quoted, Brunton⁵ gives a tracing of an irregular pulse induced by digitalis, which leaves no doubt of its nature, if the measurement used by Wenckebach be employed.¹⁷ This case was reported in 1865, and since that time has been frequently referred to as an instance where digitalis "quickens the rate, then slows it"; but the true explanation is that the digitalis had produced a partial heart-block, and that the irregularity was of the same kind as that described in *CASE 27*.

In 1905 I published a case of partial heart-block resulting from digitalis,¹³ In this case, previous to the administration of digitalis, there had been a prolongation of the *a-c* interval, and this implied an injury to the *A-V* bundle. In a number of cases, observed since then, in which there had been a wide *a-c* interval, digitalis had this same effect with the exception of one case where a curious standstill of the whole heart was produced.

Among the cases observed at Mount Vernon Hospital partial heart-block was produced by digitalis in six. In only one, not included in this series, was there a wide *a-c* interval before the administration of digitalis, and in this instance heart-block was produced on several occasions by digitalis. The changes due to digitalis in this patient have been described by Lewis elsewhere.¹⁰ This patient subsequently contracted pneumonia and died, and a lesion was found affecting the *A-V* bundle. In the remaining five cases (*CASES 17, 18, 21, 24, 27*), the increased interval on digitalis was not constant, but occurred at intervals, and was usually accompanied by dropping out of ventricular beats, giving rise to irregularities in the pulse. In *CASE 27* these periods of irregularity in the pulse resulting from partial heart-block were produced on three occasions, and while they were present the patient's condition was distinctly improved. In tracings of the jugular pulse it will be observed that there is a very large wave *v*, filling up the whole period of the ventricular systole (Fig. 38 and 39). In most of the tracings from the jugular there was no evidence of the auricular wave, so that the appearance of the jugular pulse was of the ventricular form with regular heart action. At times we were able to get a small wave due to auricular systole, so that in this case we could infer that the auricle was contracting regularly, but that owing to the great engorgement of the right auricle, its force was so slight that it barely communicated a wave to the jugular vein. When the partial heart-block was present, we could occasion-

ally detect a small auricular wave between the large waves, and on the assumption that the auricle was contracting regularly, but that the stimulus occasionally failed to reach the ventricle, the diagrams in Fig. 38 and 39 were constructed. In these figures in addition to the small wave (*a*) between the large waves, a small wave is occasionally perceived on the large wave, which I interpret as due to the auricle contracting while the ventricle was still in systole; the accompanying diagram, constructed on this view, shows the auricle contracting at regular intervals. This interpretation is confirmed by the electrocardiogram, taken during the period of irregularity when Fig. 38 and 39 were obtained. In Fig. 52 the electrocardiograms of this patient are given, and they show that the auricular systole (*P*) occurred at regular intervals and occupied a varying relation to the ventricular systole (*R*, *T*); they confirm the diagram which interprets Fig. 38 and 39.

In the other cases the falling out of the ventricular systoles was not so frequent, but the tracings of the jugular pulse showed a distinct increase in the *a-c* interval. In *CASE 21* the block only occurred after exertion, not at once, but after the heart's rate had become slower.

It is of interest to note in *CASE 27* that, although the ventricular rate (and pulse rate) was slowed, there was no slowing of the auricular rate. This is shown in the chart, Fig. 41, where the solid line represents the auricular rate and the interrupted line the ventricular rate, during the period of partial heart-block.

In all cases when the digitalis was stopped, the ventricular intermissions disappeared in a few days. In *CASE 18* variations occurred in the auricular rate, and when the auricle was acting slowly the ventricle contracted independently of the stimulus from the auricle (Fig. 30). These "phasic" variations with the escaped ventricular beats have been dealt with very fully by Lewis.

It is necessary to draw attention to the effect of digitalis in *CASE 17*. She had digitalis given her on three occasions until nausea was produced. On the first occasion, no change could be detected in the heart, but on the second occasion she had auricular fibrillation for four days (commented upon at page 287); on the third occasion she showed an occasional intermission which on examination was found to be due to partial heart-block, and there was also a delay in the transmission of the stimulus from auricle to ventricle (Fig. 28). I mention this as it may be of some significance in clearing up the obscurity of the production of auricular fibrillation, and the peculiar susceptibility to digitalis..

The presence of heart-block is not necessarily a contra-indication to the use of digitalis. When it is complete, it cannot interfere with the conduction of the *A-V* bundle, for conduction is abolished, and so far there is no evidence that digitalis has any effect on the idio-ventricular rate. *CASE 39* demonstrated complete heart-block, and though digitalis had an effect on his digestive and nervous systems, and upon the urine secretion, it had no perceptible effect on the heart's rate.

Effect of digitalis on tachycardia.

Abnormal increase in the rate may be due to many causes, and the heart's contraction may start at several places besides the normal starting place. Tachycardias with the contraction starting at the normal place are due as a rule to some toxin or fever, such as accompany tubercular disease, alcoholism, acute pneumonia and other febrile complaints. So far I have found such hearts unaffected by digitalis, even when it is pushed to the extent of causing nausea and vomiting. *CASES 41, 42 and 43*, though the increase in rate was not marked, illustrate this experience.

In tachycardias with an abnormal starting place, the most common form is that due to auricular fibrillation. Here the rate rarely exceeds 140 beats per minute and most cases are very susceptible to digitalis, as has already been pointed out. Although none are included in the cases described here, I have had a number who have drifted to a fatal end quite unaffected by the digitalis group of remedies, pushed as far as one dared.

Another group of tachycardias is that in which the rhythm is as a rule quite regular but where the contractions arise in the auricle in some place other than the normal starting place, in the *A-V* bundle or in the ventricle. Usually in these cases, the tachycardia comes in paroxysms lasting for varying periods. In some, the paroxysms tend to become continuous and unless they are stopped the heart is so exhausted that death ensues. So far no remedy has been found for such cases, although occasionally attacks may be cut short by vomiting or pressure on the vagus. In two cases recorded here (*CASES 37 and 38*), the tachycardia had become continuous, and the patients were becoming more and more enfeebled. The steady pushing of the digitalis ultimately restored the normal rhythm, but it is of interest to note that the auricle, when the decrease in rate came on in the first instance, passed into fibrillation. When this occurred the rate became slower than the normal rate and in this respect resembled *CASE 17*, where auricular fibrillation was induced by the digitalis.

Lewis has shown that paroxysmal tachycardia arising in the auricle is allied to auricular fibrillation and the possibility is that the tachycardias in these two cases were of auricular origin, and this may account for their passing into temporary auricular fibrillation.

Effect of digitalis on the heart muscle.

In my previous experience of the action of digitalis, I had failed to detect any constant decrease in the size of the heart in those cases in which great improvement had taken place. As these observations were not as complete as I wished, when we started our observations in the Hospital, the subject of the effect of digitalis on dilatation of the heart was specially studied. I had already confirmed the conclusions made by many observers

that patients with dilatation of the heart experienced the greatest benefits from digitalis. Taking the increase in size as an evidence of dilatation, we were careful to note the size of the heart during the whole time the patient was under our observation in all our cases. At first we intended to keep records by means of X ray observations, but this method was found impracticable. We were therefore forced to depend on percussion as our method of observation. As some slight difference in percussion is usually obtained by different individuals, the observations of individual patients were made only by one of my colleagues. The results obtained showed variations so slight and within the limits of error that we could place little reliance on such variations as were noted. Allowing for small errors, the broad fact stands out that in the great majority of cases where the digitalis had an undoubted effect upon the heart, little or no difference could be detected in the size of the heart. Even in such cases as *CASE 1*, where the patient from being a broken down wreck recovered so far as to do heavy work for many hours a day, no difference could be found in the size of the heart. In *CASE 3*, when she had attacks of great dyspnoea with lividity of face and great distension of the jugular veins, no increase could be detected by percussion during these attacks. In this case there must have been some variation in the size of the heart, and we can only surmise that percussion of the heart does not reveal the changes with sufficient precision.

A distinct diminution in the size of the heart was found in *CASE 11*, but here the rest in bed may have been the chief cause.

That changes take place in the heart which we cannot detect is possible, especially in cases where there has been dropsy. But whether the improvement is due to a cardiac, renal or vaso-motor action, we have no data on which to base an opinion.

Effects of drugs to determine the question of vagus effects produced by digitalis.

In certain cases digitalis acts on the heart by slowing the rate and by strengthening the beat. We attempted to find out how these effects were produced by seeking answers to the following questions. (1) Was the slowing the outcome of a direct action on the heart muscle, or an indirect one through stimulation of the vagus? (2) Was the stronger beat due to the longer rest induced by the slow rate or was it also due to an action on the muscle? To answer the first of these questions we tried to decrease the heart's rate by other means. To this end we used aconite as a substitute for the digitalis, as there is a widespread belief in its power of slowing the rate of the heart and some authorities state that in this respect its action results from stimulation of the vagus. In order to ascertain if the decrease in the rate was due to vagus stimulation, we employed atropine to paralyse the vagus action in certain cases where the digitalis had acted on the heart's rate. To find if the action was on the muscle we used helleborein.

Action of aconite. We gave tincture of aconite to a number of patients, and carefully watched for an effect. We began by giving 5 minims every two hours, then increased the dose to 10, and finally to 15 minims. Although the dose was given for several days in many cases, not the slightest effect could be detected. We tried three different preparations, one of them said to be "standardised," and all without effect on the heart or other organs.

At Professor Cushny's suggestion we then used aconitine, and Dr. Price carried out a series of observations on its action. He employed the drug in cases of fibrillation of the auricle in which digitalis was effective. He employed it in numerous cases with rapid heart action, due to fever and other causes, and carefully pushed the drug in such cases till the patient felt tingling of the tongue and skin, and in not a single instance did he get any evidence of a reaction on the heart or blood vessels.

The action of atropine in hearts under the influence of digitalis. In cases where the heart was slowed from the action of digitalis, the effect of the atropine speedily increased the rate, usually to that which

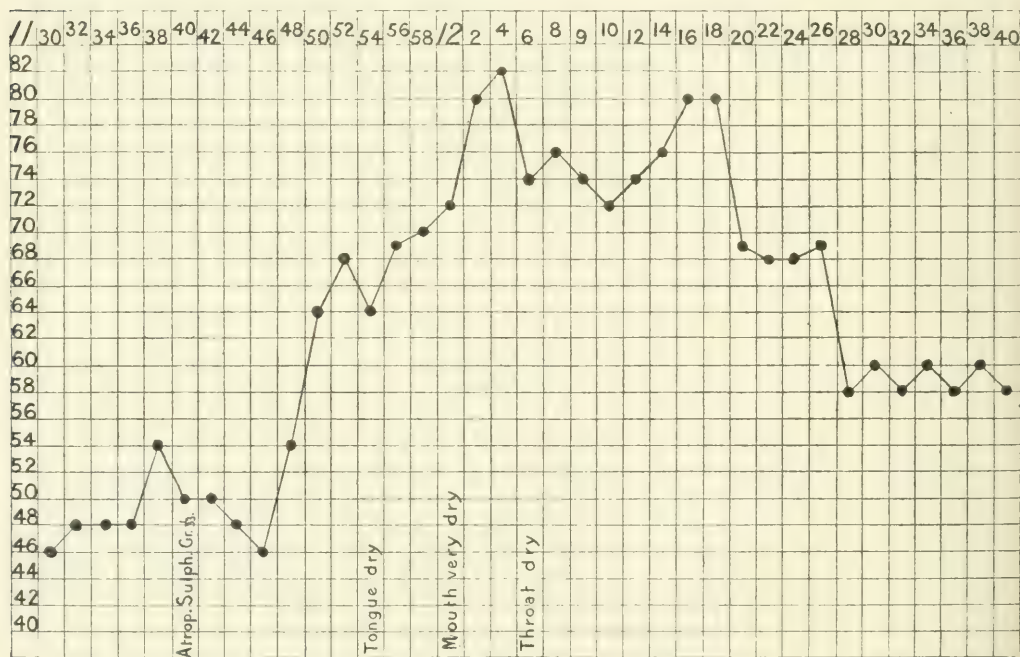


Fig. 2. Chart of CASE 1, showing the effects of atropine on a patient under the influence of digitalis. The numbers at the side represent pulse beats, those at the top minutes.

preceded the action of the digitalis. The chart (Fig. 2) shows its effect on CASE 1. In this patient the heart rate when free from the effect of digitalis was usually about 80 per minute. Under the influences of small

doses of digitalis it could be kept between 40 and 50 beats. The effect of atropine was tried after he had been taking small quantities of the tincture of digitalis for months. The pulse was fairly regular and its rate was 44 per minute before the injection of 0.03 grains of atropine. In six minutes the rate began to rise, and reached 82 per minute—the rate usually present when free from digitalis—24 minutes after the injection of atropine. The effect began to pass off 40 minutes after the injection, but at the end of the hour during which I took a continuous tracing by means of the ink polygraph, it had not quite passed off (Fig. 2). Dr. Silberberg carried out a series of observations on a number of patients under the influence of digitalis and all confirmed this result. In *CASE 5*, when there were continuous coupled beats, the atropine abolished the coupled rhythm. In *CASE 27*, when partial heart-block was present, and the ventricular rate was 84 per minute, the atropine abolished the block and the ventricular rate rose to 110-120.

So far as our observations go, the action of atropine in increasing the rate, when it has slowed, seems to indicate that digitalis acts through the vagus nerve, both in the slowing which occurs in auricular fibrillation and in partial heart-block. This is supported by the fact that it is sometimes possible to produce partial heart-block by pressure of the vagus in the neck, while an observation of mine revealed partial heart-block in a patient under the influence of digitalis whenever he swallowed—the heart block being of the same nature as that which appeared spontaneously when he was more fully under the influence of digitalis. Later observations show that there are other influences at work in slowing the rate.

The effect of drugs allied to digitalis.

Helleborein. Cushny states that helleborein acts on the heart muscle by strengthening the beat. At his suggestion, we tried the drug in cases susceptible to digitalis, but we could get no perceptible effect, although some of the patients stated that they were more conscious of the force of the heart beat.

Strophanthus and squills. An attempt was made to compare the efficiency of other members of the digitalis group of remedies with digitalis. In my experience, I had found that if digitalis failed to act beneficially, these other drugs also failed. Inasmuch as digitalis was sometimes badly borne, causing nausea and headache, it seemed that strophanthus, squills or helleborein might prove free from these unpleasant effects.

So far this hope has not been realised, but our observations are too few to settle the matter.

Strophanthus. The preparation used was the B. P. tincture and in those cases in which strophanthus acted on the heart, slowing its rate, we found digitalis also acted. We found no case in which digitalis failed and strophanthus succeeded. Auricular fibrillation cases, such as *CASES 7* and *9* were very susceptible to strophanthus, two to four drachms markedly slowing

the heart. On the other hand, *CASE 10* took forty drachms (1-2 drachms per day) with only slight effect upon the heart. *Strophanthus* had, like *digitalis*, only a slight effect upon the heart's rate with the normal rhythm. It is in its action on the digestive tract that *strophanthus* is so variable. While some patients took as much as 23 drachms (*CASE 25*) and 40 drachms (*CASE 10*) with no intestinal disturbances, others (*CASES 7, 9, 19 and 26*) had diarrhœa, sometimes severe, after 2-6 drachms. (The preparation used was physiologically assayed by Professor Cushny, who found it twenty times stronger in its effect on the exposed heart of the frog than the *digitalis* we used. But in view of the fact that Cushny has found that the tincture of *strophanthus* loses its effect when mixed with water we have to repeat our observations.

Squills. The preparation used was the B. P. tincture. As a rule squills had little effect upon the heart. Like *digitalis*, it caused headache, but only when large doses were taken. Thus *CASE 7*, who at first suffered much from headache when *digitalis* slowed the heart after seven or eight drachms had been taken, took 19 drachms of tincture of squills with little effect on the heart, but it caused headache. *CASE 9*, who was susceptible to $2\frac{1}{2}$ - $4\frac{1}{2}$ drachms of tincture of *digitalis* took 48 drachms of tincture of squills, with only a slight effect on the heart, but severe diarrhœa. *CASE 3*, who was very susceptible to *digitalis*, took one drachm of tincture of squills for twenty days with no effect. In those patients with the normal rhythm (*CASES 30 and 33*), who took 11 and 20 drachms respectively, there was no effect. On the other hand, *CASE 24* had partial heart-block and extrasystoles after 10 drachms, though she continued to take the drug with no disagreeable effect until she had taken 20 drachms (see Dr. Turnbull's analysis of these cases.¹⁶)

DETAILED REPORTS OF CASES.

CASE 1, male, aged 24. Auricular fibrillation. Mitral stenosis. Rheumatic history. Marked improvement in general health and slowing of rate after digitalis.

Admitted February the 8th, 1910. Complaining of weakness, shortness of breath and palpitation.

History. The patient had had two attacks of rheumatic fever at 12 years and 18 years of age. After the last attack, he was told his heart was affected, and he had been giddy and short of breath at times ever since. He had not been able to work for a year, and had lain in another hospital for four months before admission to the Mount Vernon Hospital.

State on admission. The patient's breathing was rapid (22-30) and laboured; he lay propped up in bed. The pulse was continuously irregular and the rate varied from time to time during the examination; at one time it was 117, and at another time 78 (Fig. 3). There was a large area of cardiac

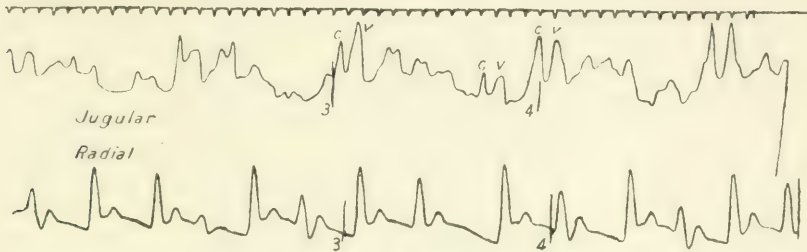


Fig. 3. Simultaneous tracings of jugular and radial pulses from *CASE I*. The irregularity is characteristic of auricular fibrillation, the rate is 78 per minute; the patient was not under the influence of digitalis.

pulsation of the 3rd, 4th, 5th and 6th interspaces, the most prominent beating being in the 5th space outside the nipple line. The margins of the heart's dulness lay $1\frac{1}{2}$ and 6 inches to right and left of the middle line. There was a systolic murmur, heard loudest at the apex. Here there was also a soft short murmur following the second sound. At the base the second sound was markedly reduplicated and no murmur was heard. The liver was enlarged and could be felt to pulsate three inches below the level of the ribs.

Treatment and progress. The patient was treated by rest only for ten days, and made a slight improvement, though he at once became worse if he walked a few yards. On February the 19th, he was put on 15 minims tincture of digitalis, four times a day. Under the influence of the drug the pulse became slower, and in a few days the patient's condition rapidly im-

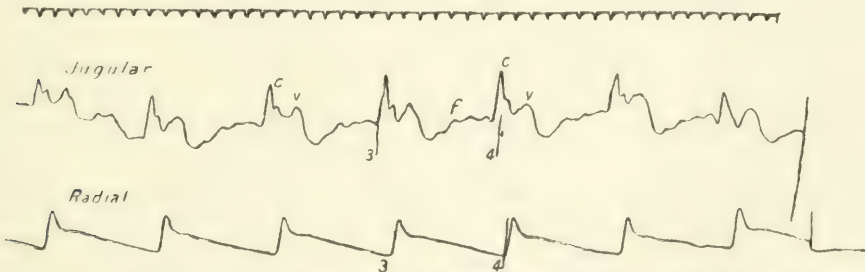


Fig. 4. From the same patient as Fig. 3 (*CASE I*) after 10 drachms of tincture of digitalis. The pulse rate is 42. The jugular tracing shows the series of small waves (*f*) characteristic of fibrillation.

proved. After he had taken 11 drachms, there was a good deal of nausea, and the drug was stopped on March the 2nd. The nausea disappeared in a few days and the patient felt much better. The pulse remained slow and almost regular (see Fig. 4), though there was no return of the normal rhythm. On March the 9th the pulse rate began to increase. He was put on helle-

borein on March the 13th in doses at first of $\frac{1}{10}$ grain, and later $\frac{1}{2}$ grain, six times a day, till March the 21st, when the drug was stopped for a day or two as the rate of the heart continued to rise, and there was at times a distressing flutter of the heart. The helleborein was resumed on the 22nd in doses of $\frac{1}{2}$ grain three times a day, but diarrhœa set in and the drug was stopped after a couple of days, $15\frac{3}{4}$ grains having been taken in 13 days. The pulse rate became very irregular and increased in rate, continuing from 74 to 82, and the patient was very breathless and weak on exertion. On April the 1st he began again with the digitalis, 15 minims four times a day, and this was continued till April the 11th, when he had taken 10 drachms. His pulse rate had fallen under 50, and was almost regular, and he felt much better and breathed more easily, but as nausea appeared, the drug was stopped for a few days. When the nausea had passed off, he felt very well, and on April the 13th, the digitalis was resumed in doses of 15 minims thrice daily. This quantity kept the pulse rate between 45 and 50 beats per minute, without producing any disagreeable symptoms. He felt very fit when discharged from the hospital on May the 29th, and resumed his work (see Fig. 5).

On November the 13th, 1910, he called to report himself. For a month after leaving the hospital he had taken 30 minims of tincture of digitalis daily. During the second month 15 minims once a day, and after that he had taken three or four doses of 15 minims a week, sometimes going several days without any medicine. The indication which guided him was his pulse rate, if it was about 50, he was well, but when it began to get rapid after exertion he took a few doses of his digitalis and felt quite well again. While the digitalis kept the pulse slow, he was quite fit for work (organ grinding). The organ is a heavy one, and he drags it himself, sometimes as far as 20-25 miles a day, and he seldom leaves off before 7 p.m., with the exception of half hour for dinner. When examined his pulse was 54 per minute, fairly regular for short periods, but showing in the jugular the characteristic signs of auricular fibrillation.

On December the 15th he called on me, and was still working and feeling very well. The heart rate was usually from 45 to 50 per minute. Occasionally it increased in rate, and the heart "fluttered," but a dose of digitalis always slowed it down. The last few weeks, prior to seeing me, he had taken about 1 drachm of the tincture per week. After recording the pulse rate for about 10 minutes, a hypodermic injection of atropine sulphate containing 1-33 grain was given. The pulse rate was graphically recorded for one hour after. In 6 minutes the rate increased, reaching 80 about 20 minutes after the injection. It continued at this rate for about 20 minutes and then fell to about 60 for the remaining 20 minutes he was under observation (Fig. 2).

It is to be noted that although there was a great improvement, the size of the heart and the nature of the heart's rhythm did not alter, the auricular fibrillation still persisting.

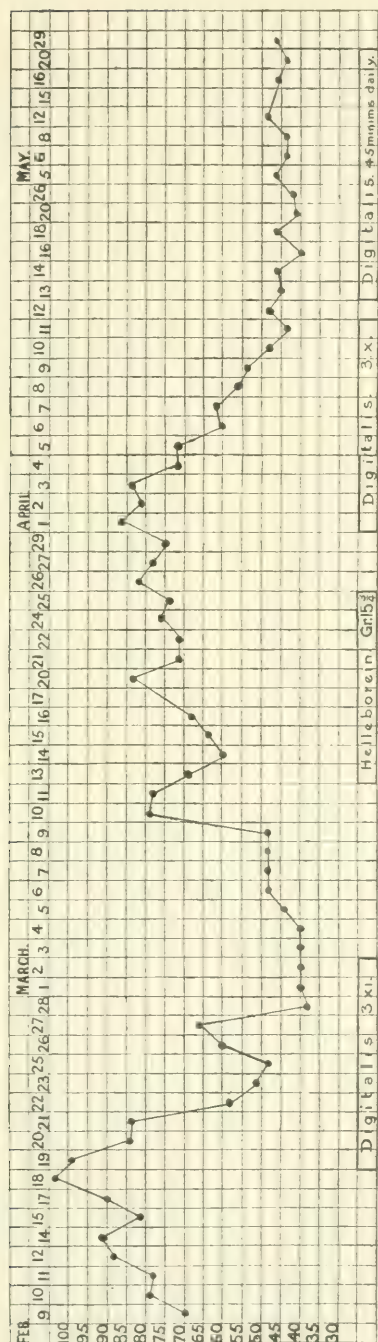


Fig. 5. Chart of *C. A. S. E. 1*, showing the effect of digitalis, etc. The numbers at the side represent pulse beats, those at the top days.

DATE	DRUG.	PULSE RATE.	URINE.	SIZE.	REMARKS.
Feb.					
9		70	25		
10		79	53		
11		78	45		
12		88	58		
14		93	44	1½-6	Short of breath, palpitation, pain over precordium, lies propped up in bed.
15		82	58		
17		90	42		
18		108	62		
19	Digit. 5i p. d.	99	61		
20		84	56		
21		84	53		Not sleeping well, has to sit up two or three times in the night.
22		58	60		
23		52	75		Feels fairly well, nausea.
25		48	61		Feels fairly well, nausea.
26		60	52		Feels "sick at stomach," able to sit up in chair for 1½ hours.
27		66	62		Can sleep lying flat.
28		38	34		More nausea. Can walk about in comfort.
March.					
1		40	52		Feels better, nausea nearly gone.
2	5xi Digit. stopped	40	53		Not so well to-day, feels sick at stomach.
3		40	29		Feels queer. Headache. Nausea.
4		40	36		Feels better, no nausea.
5		44	35		Still improved, no nausea.
6		48			
7		48			Feeling well.
8		48			
9		48	40		Not so well, palpitation, short of breath last night.
10		79	53		
11		78	45		Not so well, giddy and dyspnœic, palpitation.
13	Helleborein	69			
14		60	44		Feels poorly.
15		64	54		
16		68	38		Feels poorly, palpitation on exertion.
17			55		
20		84	56		Fluttering of heart and dyspnœa on exertion.
21		72	37	1½-5¼	
22		72	44		
24		76	17		Palpitation on slightest exertion, diarrhœa.
25	Gr. 15¾ Helleb. stopped	74	38		Complains of "thumping" of heart. Diarrhœa.
26		82	60		
27		78	63		
29		75	64		
April.					
1	Digit. 5i p. d.	87	53	1½-6	Feels as though heart were beating very fast, "thumping."
2		81	65		
3		84	58		
4		72	31		No definite change, except less breathlessness after exertion.
5		72	63		Breathing quite easy in bed.
6		60	47		Feels well, breathing easy, less breathless after exercise.
7		62	70		One minute after exercise, pulse rate fell to 50.
8		56	63		Feels well, breathing easy when quiet. Slight nausea in night but good appetite.

DATE.	DRUG.	PULSE RATE.	URINE.	SIZE.	REMARKS.
April. 9		54	52		Feels fairly well, slight nausea. One minute after exercise, pulse rate fell to 45.
10		48	46		Feels sick, slight nausea.
11	3x Digit. stopped	44	61	1 $\frac{1}{4}$ -5 $\frac{1}{2}$	Feels sick, vomited last night. Breathing easy, feels heart thumping occasionally.
12		48	31		Feels very well, though slight nausea. Slightly breathless after exercise.
13	Digit. 45 minims	45	39		Feels well, slept well, no nausea now.
14	p. d.	46	40		
16		40	62		Breathing easy, no nausea but feels heart thumping and beating. Pulse fell to 36 2 minutes after exertion.
18		46	47		Feels well, no nausea. Feels heart beating a good deal. Pulse rate fell to 45 5 minutes after exercise.
20		42	34		
26		43	48		No nausea for some days.
May. 5		46	55		
6		64	66		
8		44	75		Feels well, heart still thumps after exertion.
12		48	66		
15			84		
16		46	79	1 $\frac{1}{4}$ -5 $\frac{1}{2}$	Felt a little nausea last night. Breathing easy.
20		44	60		
21			45		Feels well, but heart thumping a good deal.
25			76		Feels well.
29		46	51		Feels well, able to go upstairs in comfort.
Nov. 13		54		1 $\frac{3}{4}$ -6 $\frac{1}{2}$	Feels well and working. (See notes).
Dec. 15		48			Feels well and working. (See notes).

CASE 2, female, aged 35. Auricular fibrillation. Mitral stenosis. Rheumatic history. Marked improvement and decrease in pulse rate after digitalis. Kept well on small doses. No effect from aconite.

Admitted June the 14th, 1910. Complaining of cough and shortness of breath.

History. She had been short of breath as long as she could remember but had been worse during the few years prior to admission, and sometimes very bad, especially after a period of rest. She had rheumatic fever at the ages of 12, 14 and 17.

State on admission. The patient was well nourished, the face was dusky and the lips dark red. The legs were slightly swollen; she was able to go about, but was very breathless. The pulse was continuously irregular, 84 beats per minute. The jugular pulse was of the ventricular form. The heart's impact was slight, the apex beat was in the 6th interspace, and the heart's dulness lay 1 $\frac{1}{2}$ and 6 inches to right and left of the mid-sternal line.

There was a systolic murmur heard loudest at the apex, and a diastolic murmur heard only at the apex.

Treatment and progress. The patient was allowed to rest in bed with no medicinal treatment for a week. During that time the pulse rate fluctuated between 76 and 84 beats per minute. On June the 26th she was put on tincture of aconite, 5 minims every two hours during the day (receiving 8 doses per day). This was continued till July the 4th when the dose was increased to 15 minims every two hours. The pulse had gradually increased in rate, sometimes being as high as 112 beats per minute. The aconite was stopped on July the 7th, the pulse rate being 100 at that date. On July the 8th she was given

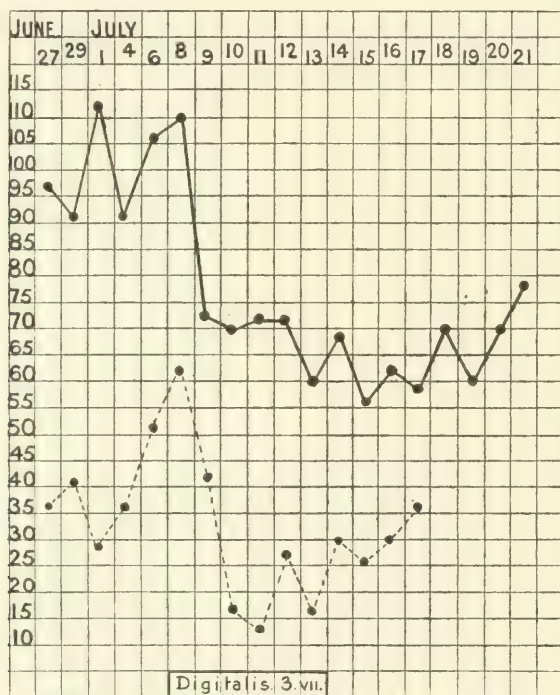


Fig. 6. Chart of C A S E 2. Showing pulse rate (solid line) and urine flow in ounces (interrupted line).

tincture of digitalis, 30 minims thrice daily, and this was continued till July the 13th, when she had taken $7\frac{1}{2}$ drachms. The pulse had fallen to 60 beats per minute, and there was a good deal of headache and nausea, but no vomiting. The headache and nausea persisted and she vomited on the 14th. She had no appetite. By the 19th all the disagreeable sensations had disappeared and she felt very well, the pulse rate being 60. After that date the patient felt better and the pulse rate fluctuated between 60 and 80 beats per minute till her discharge on August the 4th.

After leaving the hospital she stopped taking the digitalis and she became gradually more breathless and cyanosed and the legs swelled. She called at the out-patient department on August the 23rd, and was put on tincture of digitalis, one drachm per day, and she improved at once. During November and till December the 7th she took 45 minims of the tincture per day and felt very well on it, and was able to do her household duties. When last seen (December the 7th) she looked much less dusky and felt very well. The pulse rate was 84 beats per minute after walking and sitting down for a few minutes (see Chart, Fig. 6).

DATE.	DRUG.	PULSE RATE.	URINE.	SIZE OF HEART.	REMARKS.
July.					
6		106	37	1½-6	
8	Tr. Digit. 30 minims	110	41		
9	90 minims	73	29		
10	" "	70	37		
11	" "	72	52		
12	" "	72	63		Headache.
13	60 minims	60	42		Headache, nausea, no appetite.
14		68	16	1½-6	Vomited. Headache.
15		57	14		Vomited. Headache.
16		63	27		Better, no vomiting.
17		59	16		
18		70	30		
19		60	26		
20		70	30		
21		78	57		Breathing much easier.

CASE 3, female, married, aged 33. Auricular fibrillation. Mitral stenosis. Rheumatic history. Marked improvement and decrease in pulse rate while under the influence of digitalis. No effect from squills.

Admitted July the 13th, 1910, complaining of shortness of breath, cough and palpitation.

History. The patient had had frequent attacks of "rheumatism" ever since the age of ten. She had known that her heart was affected since she was eleven years old. She had suffered from repeated attacks of heart failure, at times with great distress in breathing, and had been 43 times in hospital; she had been bled 27 times for attacks of "asthma," always with relief. She had been very ill twelve days before admission, with shortness of breath, cough and palpitation.

State on admission. The patient lay propped up in bed, the face dusky, breathing laboured. The pulse was small, irregular and rapid, 114 beats per minute (Fig. 7). The deep jugular veins were distended and pulsating. The chest was somewhat emphysematous, and there were numerous râles all over the lungs. The heart's apex was in the 6th interspace, and the heart's dulness lay 2 and 6¾ inches to right and left of the mid-sternal line. At the apex there was a systolic murmur and a reduplicated second sound, and, when the heart had slowed, there was a well marked diastolic murmur at the apex. The knuckles of both hands were enlarged and the

fingers distorted. The liver was three inches below the ribs and pulsated. There was slight oedema of the feet.

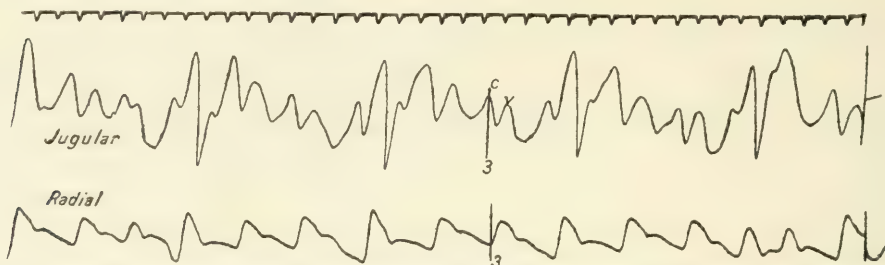


Fig. 7. Simultaneous tracings of the jugular and radial pulses from CASE 3. The irregularity is characteristic of auricular fibrillation, the jugular pulse is of the ventricular form, the rate is 104 per minute, the breathing is laboured, and disturbs the tracings of the jugular and radial during inspiration. The patient was not under the influence of digitalis.

Treatment and progress. The patient's distress was so great that she was at once placed on tincture of digitalis, 30 minims three times a day, and this was continued for three days till she had taken $4\frac{1}{2}$ drachms. She began to vomit after she had taken three drachms, and the vomiting continued till the drug was stopped. With the onset of vomiting, the breathing became greatly relieved and the heart's rate fell. The vomiting ceased the day after the digitalis was stopped and the patient was very much better in every way. The patient stated that she was very liable to attacks of breathlessness, but so long as she was under the influence of digitalis she did not suffer from them. She was therefore given digitalis again, 1 drachm per day on July the 30th. After she had taken $4\frac{1}{2}$ drachms (August the 5th) the vomiting returned, and the pulse rate fell (Fig. 8), sometimes it was as low as 46

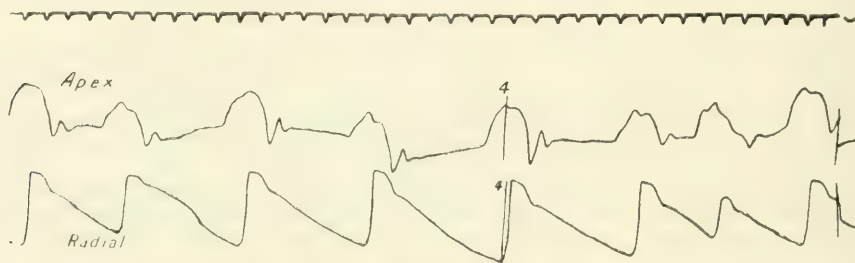


Fig. 8. Simultaneous tracings of the apex beat and radial pulse, from CASE 3, after the patient had taken $4\frac{1}{2}$ drachms of tincture of digitalis. The patient had greatly improved, the jugular pulse had disappeared and the pulse rate had fallen to 52.

beats per minute and the drug was therefore stopped. When the heart's rate fell there were frequent periods when the pulse became very slow, and it was found that the heart was beating with the coupled rhythm. By the 10th all the disagreeable symptoms had passed off, the rate rising to 78 per minute, and she was put on tincture of digitalis, 10 minims three times a day. This speedily induced headache and the coupled rhythm of the heart, so that the pulse rate fell to 44 per minute—the rate of the heart being double the

number of the pulse beats. There was slight nausea on the 13th; the dose was reduced to 10 minims twice daily and this was continued till the 17th, when the patient was painfully conscious of the heart's beat, the coupled rhythm being present and now nearly continuous. The drug was reduced on the 18th to 5 minims twice daily; she woke next morning with a severe headache and mental confusion, in that she could not remember the names of people or things. She vomited and the coupled rhythm was present. The drug was stopped and in a couple of days she was much better and on the 26th there were only occasional periods of coupled rhythm; by the 27th the coupled beat had gone. As the pulse rate was beginning to quicken, she was put on tincture of digitalis, 10 minims twice daily on August the 28th, in three days the coupled rhythm returned and the digitalis was stopped. The coupled rhythm ceased and on September the 7th she was put on tincture of strophanthus, 10 minims thrice daily. On the following day she became gradually worse, the breathing became rapid and laboured, the pulse increased in rate to 132, the respirations were 60 per minute and the patient developed what seemed like a severe attack of asthma. Various remedies were tried to give her relief, but after an injection of morphia and the inhalation of oxygen the attack subsided somewhat rapidly. From this date onwards she was given digitalis in varying quantities, but she quickly responded with some disagreeable symptom and when free from digitalis she was liable to attacks of intense dyspnœa. She had several of these attacks and was bled for them: after 10 to 20 oz. of blood were withdrawn, she was always greatly relieved. The attacks were invariably accompanied by very rapid action of the heart and great distention of the veins of the neck; the pulsation of the internal jugular veins being visible behind the ear. Notwithstanding this evidence of congestion of the right side of the heart no change could be detected in the size of the heart.

From October the 16th to the 31st she was taking 20 minims of tincture of squills four times a day but it had practically no effect on the heart rate or urine secretion, and the attacks of severe dyspnœa recurred while she was taking this drug, so it was not persevered with. She had three very bad attacks on November the 7th, 8th and 9th, and on the 8th she was put on digitalis, at first one drachm a day, then, after three doses, $\frac{1}{2}$ drachm per day. The pulse rate kept between 60 and 64 beats per minute till the 19th, when it began to increase and the dyspnœa returned. The increase of the dose to a drachm per day speedily slowed the heart and relieved the breathing. The rhythm became almost regular (Fig. 53).

The ease and comfort of the patient and the freedom from the dyspnœic attacks, while partially under the influence of digitalis induced us to give her just as much as would produce comfort with the avoidance of disagreeable effects. This was attained by giving her 10 minims thrice daily and intermitting the drug on the first sign of digitalis effect, for example headache, nausea or the coupled beat. Only a portion of the notes are included as they are too voluminous to give in their entirety; but the repeated administration of

digitalis always produced effects similar to those described, the pulse increasing in rate as soon as the digitalis effect passed off.

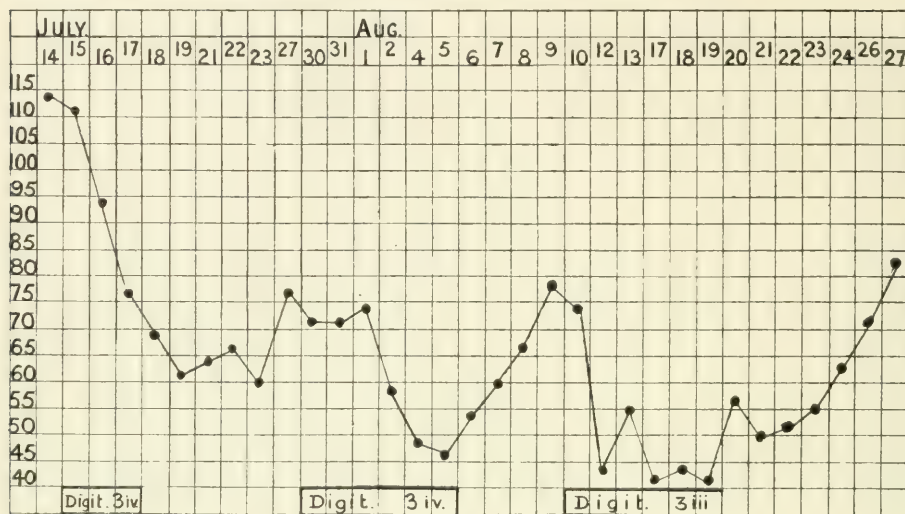


Fig. 9. Chart of CASE 3.

DATE.	DRUG.	PULSE RATE.	URINE.	SIZE OF HEART.	REMARKS.
July.					
14		114	20	2-6 $\frac{3}{4}$	Very short of breath.
15	Tr. digit. 30 m. p.d.	111	26		Very short of breath.
16	p. d.	94	55		
17	3iv Digit. stopped	76	17		Vomiting, breathing easier.
18		69	8	2-5 $\frac{3}{4}$	Vomiting, breathing easier.
19		61	26		Vomiting, breathing easier.
21		64	27		No vomiting, breathing easier.
22		66	7	2-5 $\frac{3}{4}$	Much better, can lie flat.
23		60	24		
27		77	24		
30	Digit. 3i p.d.	72	21		
31		72	26		
August.					
1		74	40		
2		58	30		
4	3iv Digit. stopped	48	44		
5		46	7		Vomiting and coupled beat.
6		54			
7		60	4 $\frac{1}{2}$		
8		66	11 $\frac{1}{2}$	2-6 $\frac{1}{2}$	
9		78	7		No coupled beat.
10	Tr. digit. 30 m. p.d.	74	38		
12		44	12		
13	20 m. p.d.	55	11		Vomiting, coupled beat.
17	" "	42	22		Coupled beats
18	10 m. p.d.	44	27		
19	" "	42	30	2-6	Headache, loss of memory, coupled beats, vomited.
20		62	27		No nausea, no headache, coupled beats more seldom.
21		55	46		
22		57	36		
23		60	34		
24		68	54		
26		76	20		
27		88	50		

CASE 4, female, aged 29, tailoress. Auricular fibrillation. Mitral stenosis. Rheumatic history. Marked response to digitalis.

Admitted January the 26th, 1911, complaining of great weakness and breathlessness.

History. The patient had rheumatic fever at the age of 8, and gastric ulcer at the age of 18. She had been delicate for years and during the few weeks prior to admission she had been exceedingly weak and ill.

State on admission. The patient lay propped up in bed, with laboured breathing. The face was suffused, and the cheeks were dusky and blotched, the nose and lips blue. The conjunctivæ were slightly jaundiced, and there were dusky blotches on the trunk and limbs. The radial pulse was small, rapid and irregular, its rate was 140 per minute. The heart's dulness lay 1 and 6 inches to right and left of the mid-sternal line. The apex lay in the 6th interspace. There was a systolic murmur at the apex and also a diastolic. The respiration was laboured, the rate being 38 per minute.

Treatment and progress. The patient's condition was of such extreme gravity that she was at once put on tincture of digitalis, 15 minims four times daily. She showed little improvement till January the 30th, when she felt more comfortable, though the heart's rate did not decrease till February the 1st. After that she rapidly improved, and when last seen, on February the 5th, she was very comfortable and bright. She was found to have a chancre, and gave a positive Wasserman reaction. She was removed to another hospital (see Chart, Fig. 10).

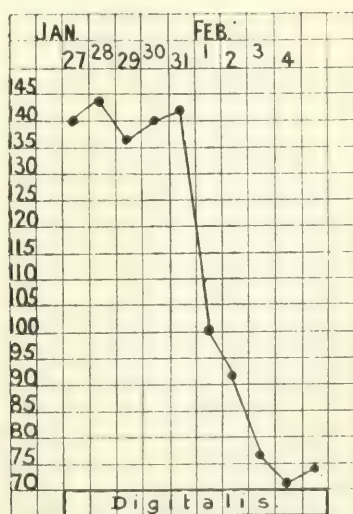


Fig. 10. Chart of CASE 4.

DATE.	DRUG.	PULSE RATE.	RESP.	URINE.	REMARKS.
Jan.					
27	Digit, $\bar{5}$ i p.d.	140	38	24	Orthopnœa. Cyanotic.
28		144	32	12	Orthopnœa. Headache. Menstruating.
29		136	28	22	Sleeping badly.
30		140	28	28	Better, more comfortable.
31		142	28	32	Comfortable.
Feb.					
1		100	32	30	Much easier, can lie flat.
2		92	28	30	Cyanosis gone.
3		76	28		Much better.
4		72	26		
5	$\bar{5}$ x Digit. stopped	74			

CASE 5, female, aged 17. *Auricular fibrillation. Mitral stenosis. Rheumatic history. Heart very sensitive to digitalis.*

Admitted August the 26th, 1910, complaining of great weakness and shortness of breath and palpitation.

History. She had had chorea at 10 years of age, and rheumatic fever in November, 1909, and had never been well since, suffering from great difficulty in breathing on exertion.

State on admission. The patient lay propped up in bed, looked very ill and was extremely emaciated. The face was pallid, the breathing laboured, 50 per minute, the pulse 144 per minute, very small and perfectly regular. The apex beat was in the 6th interspace 3 inches beyond the nipple line. The heart's dulness lay 1 and $6\frac{1}{2}$ inches to right and left of the mid-sternal line. There was a rough systolic murmur at the apex and a systolic and diastolic murmur at the aortic area. There was dulness as high as the scapular spine on the right side of the chest and absence of breath sounds over this dull area. There were numerous râles over the left side behind.

Treatment and progress. Considering the urgent condition of the patient she was at once put on tincture of digitalis, 15 minims four times a day, and this was continued for seven and a half days the patient taking altogether $7\frac{1}{2}$ drachms. There was little change in her condition for three days, when she vomited and after this the pulse rate fell (Fig. 11), and she began to improve and breathed more easily. The vomiting persisted and the pulse rate continued to fall to 45 beats per minute, and the digitalis was then stopped. The vomiting ceased when the digitalis was stopped, but day by day the pulse rate began to increase and, with the increase in the rate, the breathlessness and distress returned. She was again put on tincture of digitalis, 10 minims three times a day on September the 14th and again it speedily slowed the pulse rate but induced vomiting after six days; the drug was stopped on the 19th after she had taken $2\frac{1}{2}$ drachms. On this date the breathing was much better, she could lie flat and the extent of the dulness over the lung was greatly reduced and 10 days later it had disappeared. With

the cessation of the drug the pulse again increased in rate and the patient became alarmingly ill on October the 5th. The exhibition of the digitalis again relieved her and after this she was kept more or less under its influence for six weeks, the dose varying with the pulse rate or the condition of the stomach.

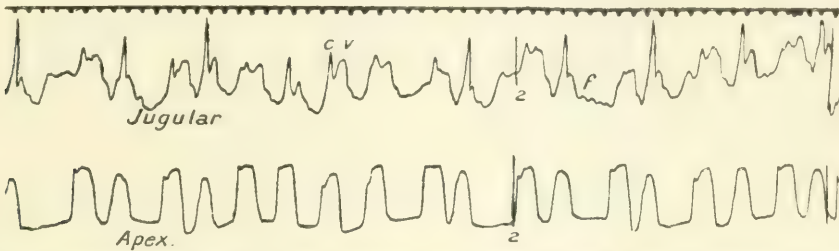


Fig. 11. Tracing of the jugular pulse and apex beat from CASE 5, after $7\frac{1}{2}$ drachms of tincture of digitalis. The rate is 96 beats per minute, and the heart shows a tendency to a coupled rhythm. Note the fibrillation waves in the tracing of the jugular pulse at *f*. The patient was free from distress.

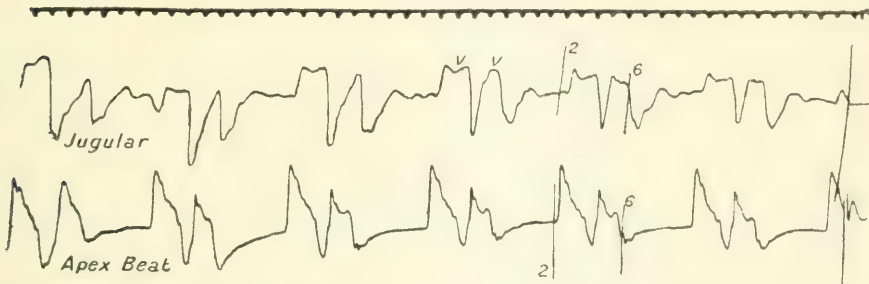


Fig. 12. Tracings of the apex beat and jugular pulse from CASE 5, showing the coupled beats maintained by small doses of tincture of digitalis.

From November the 12th she was taking 5 minims of the tincture of digitalis. This was continued till the 18th, and at this date she was feeling much better and was able to sit up out of bed. She vomited and the dose was given twice a day. She vomited on the 19th and the drug was stopped. Next day she felt much better and the vomiting ceased. The heart rate kept down, with long periods of coupled beats (Fig. 54 and 55), when the pulse rate would be between 36 and 40 and the heart's rate exactly double. On the 23rd the heart's rate increased, and on the 25th became very rapid (124) and the patient was very ill (orthopnoea, respiration 50 per minute, crepitations at the base of the lungs). She was at once put on a dose of one drachm per day and the heart speedily reacted, and in a few days she was free from all distress. Until her discharge on December the 1st, she was kept on small doses of digitalis (10-20 minims per day), and so long as the rate kept under 60 she was very comfortable in bed and able to sit up and walk a few steps (see Chart, Fig. 13).

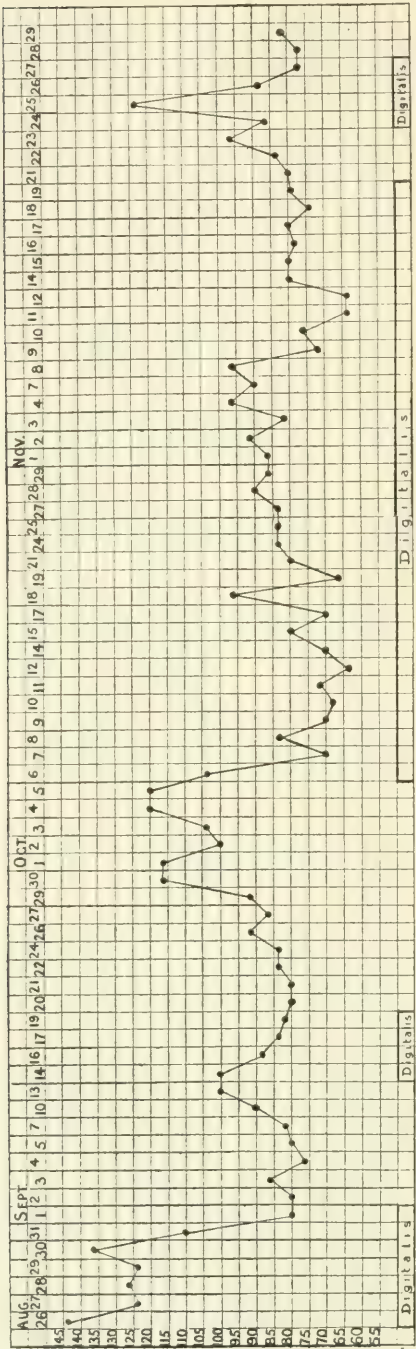


Fig. 13. Chart of CASE δ .

DATE.	DRUG.	PULSE RATE.	URINE.	SIZE.	REMARKS.
August.					
26	Digit. $\bar{5}$ i p.d.	144		1-6 $\frac{1}{2}$	Very ill.
27		124	28		
28		126	30		
29		124	10		
30		136	12		Vomited.
31		110	20		Vomited, breathing easier.
Sept.					
1	$\bar{5}$ vii Digit. stopped	80	18		Vomited.
2		80	20		Vomited.
3		86	19		Vomited.
4		76			
5		80	20		No vomiting, frontal headache.
7		82	10		No vomiting, breathing easier.
10		90	26		
13		100	20		Very breathless.
14	Digit. 30 minims p.d.	100	15		Very breathless.
16		88	26		Breathing easier.
17		84	20		
19	$\bar{5}$ ii Digit stopped	82	15		Breathing easier, but nausea (coupled beats).
20		80	8		Nausea and vomiting.
21		80	10		Nausea.
22		84	8		No nausea.
24		84			
26		92			
27		86	10		Feels much better.
29		92	20	1 $\frac{3}{4}$ -5 $\frac{1}{4}$	Feels much better.
30		116	15		
Oct.					
1		116	16		
2		100	10		Breathless.
3		104	12		
4		120			
5		120	10		Very ill.
6	Digit. 80 minims p.d.	104	12		Very ill.
7		70	12		Vomited after taking one drachm.
8	10 minims t.d.	84	10		No vomiting.
9		70	12		Feels better.
10		68	12		Feels better, breathing much easier.
11		72	10		
12	5 minims t.d.	64	12		Feels well.
14		70	16		
15		80	26		
17		70	12		Coupled beats.
18	5 minims b.d.	96	12		Coupled beats.
19	Digit. stopped	66	6		Coupled beats.
21	5 minims p.d.	80	10		Coupled beats.
24		84	10		Coupled beats.
25		84			
27		84	16		Coupled beats.
28		90			Coupled beats.
29		86	10		
Nov.					
1		86			Feels well, no coupled beats.
2		92			Breathing more hurried, no coupled beats.
3		82			Same.
4	10 minims t.d.	96			Same.
7		90			Feels a little easier.
8		96			Feels a little easier, some coupled beats.
9		72			Same.
10		76			Feels better, coupled beats.
11		64			Vomited twice, feels sick.
12		64			Feels much better, coupled beats.
14	5 minims t.d.	80			Vomited last night, nausea, coupled beats
15		80			Feels sick, no vomiting.

DATE.	DRUG.	PULSE RATE.	REMARKS.
Nov. 16		78	Feeling less sick, coupled beats.
17		80	No nausea, some coupled beats.
18	Digit. 5 m. b.d.	74	Vomited this morning, some coupled beats.
19	Digit. stopped.	78	Vomited this morning, feels better, some coupled beats.
21		80	Feels well, no headache, coupled beats.
22		84	Same.
23		96	
24		86	
25	Digit. 5i p.d.	124	Very ill, orthopnoea, respiration 50.
26		88	
27		72	
28		72	Much better, able to lie down in comfort.
29		76	

CASE 6, male, aged 33. Auricular fibrillation. Mitral stenosis. Syphilitic history. Digitalis decreased the rate, but caused vomiting, which was followed by marked improvement.

Waiter. Admitted August the 25th, 1910, complaining of shortness of breath and cough.

History. The patient gave a history of syphilis and showed a positive Wasserman reaction. There was no rheumatic history. In February, 1910,

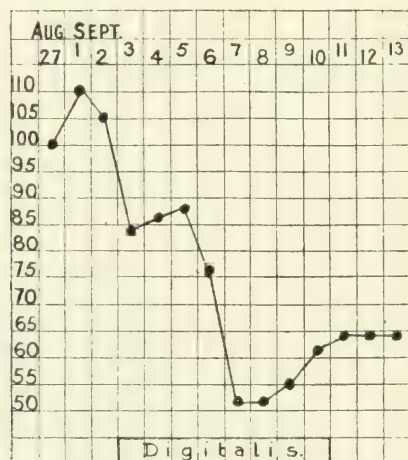


Fig. 14. Chart of CASE 6.

he became short of breath and his legs swelled and he was treated in a hospital, receiving digitalis and making a fair recovery. He broke down again and was admitted to Mount Vernon Hospital.

State on admission. The patient was pale and spare, and lay with his shoulders raised. The pulse was small, weak and continuously irregular, the rate was 80-100 per minute. The heart's dulness lay $1\frac{1}{2}$ and $4\frac{1}{4}$ inches to right

and left of the mid-sternal line. There was a rough systolic murmur, loudest at the apex and propagated into the axilla. There was also a diastolic murmur at the apex.

Treatment and progress. The patient was very weak and breathless, and after a week's rest he was put upon tincture of digitalis, 20 minims four times a day, on September the 3rd. He speedily reacted to the digitalis, feeling somewhat better after two drachms had been taken, and much better and able to undertake exertion on the 6th, when he had taken 4 drachms. On the 7th he began to be nauseated and he vomited on the 9th after he had taken 8 drachms. The following day the patient felt much better, and his condition keeping good he left the hospital at his own request on September the 14th, feeling fit for work (see Chart, Fig. 14).

DATE.	DRUG.	PULSE RATE.	URINE.	REMARKS.
Aug. 27		100	51	Short of breath on slight exertion.
Sept. 1		110	68	
2		105	61	
3		84	63	
4	Digit. 80 m. p.d.	86	63	Much less breathless on exertion.
5		88	66	
6		76	66	
7		52	67	Nausea two hours after each dose.
8		52	65	Nausea, two hours after each dose.
9	3viii Digit. stopped	55	66	Vomited three times during night.
10		62	58	Nausea gone, feels better.
11		64	71	Feels well.
12		64	68	
13		64	74	Feels well can walk upstairs without distress

CASE 7, male, aged 36. Auricular fibrillation. Mitral stenosis. Rheumatic history. Digitalis and squills improved the heart but caused headache. Strophanthus improved the heart but caused diarrhœa.

Carman. Admitted February, 1910, complaining of shortness of breath and swelling of legs.

History. The patient had rheumatic fever at the age of 16. After this he was quite well and worked hard till four years ago, when he noticed his heart beating rapidly. Shortly after this, on carrying a sack of coals, he was suddenly seized with shortness of breath and tightness across the chest and in the pit of the stomach. He had to stop work for a few days, and afterwards was unable to continue long at work; during 1906 he was six months in hospital. Afterwards he was frequently compelled to seek hospital treatment and was admitted to the Mount Vernon Hospital immediately on his discharge from another hospital, where he had lain unrelieved for nine weeks.

State on admission. The patient lay in bed propped up. He became very distressed in breathing if he lay down. His face was of a dusky red. His legs were swollen. The pulse was small and continuously irregular, about 90 beats per minute (Fig. 15). There was swelling and large pul-

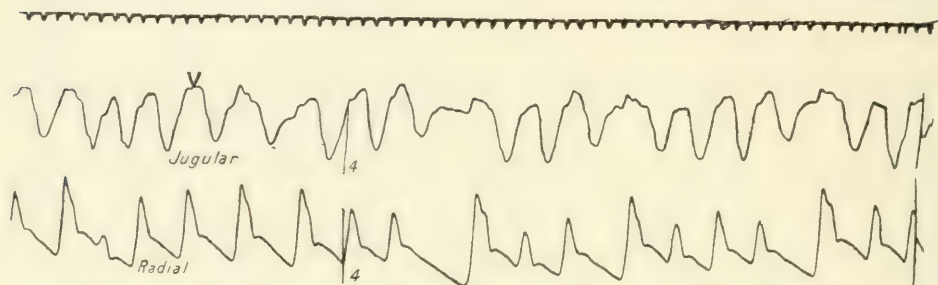


Fig. 15. Radial and jugular tracings from CASE 7, before digitalis. Rate 88.

sation of the ventricular form in the jugular veins. When pressure was applied over the liver, the deep jugular vein became enormously distended. The heart was greatly enlarged, the apex diffuse in the 6th interspace. The heart's dulness lay 2 and 7½ inches to right and left of the mid-sternal line. There was a rough murmur, systolic in time, heard loudest at the apex. Here also there was a short murmur following the second sound. The liver was enlarged as low as the umbilicus and pulsated. The liver pulse was of the ventricular form.

Treatment and progress. The patient was treated by rest in bed for the first fortnight, and made some slight improvement, though he was still very breathless. He suffered at times from headaches which became very severe while he was under the influence of digitalis. On March the 5th he was put on tincture of digitalis, 15 minims four times a day. This was continued

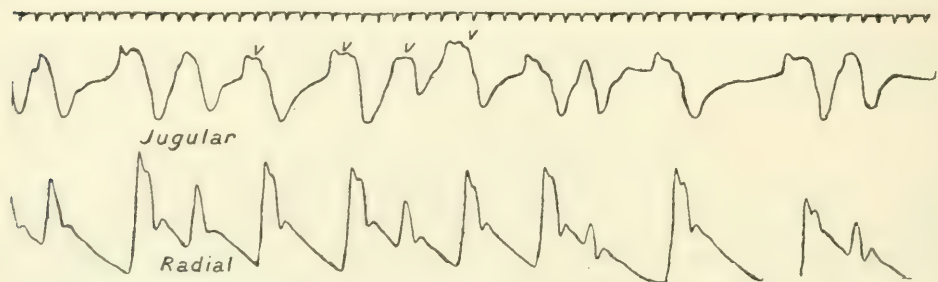


Fig. 16. Tracing of jugular and radial from CASE 7, after digitalis. Rate 66.

till the 13th, when he had taken 9 drachms. The pulse rate became slow, falling to 66 beats on the 9th (Fig. 16). There was a distressing sensation of throbbing of the heart but the dropsy had disappeared, the liver was much reduced and the veins of the neck less distended. On account of the severe

headaches the digitalis was stopped on the 13th. The effects of the digitalis passed off in a few days, his breathing became distressed and the pulsation and swelling of the jugular vein increased and the heart's rate quickened. On April the 1st he was very ill and was put upon tincture of strophanthus, 30 minims four times a day, and this was continued for three days. His heart's condition rapidly improved, but he felt ill with headache, vomiting and diarrhoea. Gradually the disagreeable symptoms disappeared and for a time he felt better, but as the effects of the strophanthus passed off, his heart again gave way. We endeavoured to find a remedy which would improve his heart's condition without any disagreeable accompaniment, but whenever an effective quantity of digitalis was taken he suffered from severe headache, and when an effective quantity of strophanthus was taken he suffered in addition from diarrhoea. We tried tincture of squills, but it acted like the digitalis in benefiting the heart but inducing severe headache. As he always relapsed when digitalis, strophanthus and squills were stopped, we kept him on digitalis intermittently and in smaller doses, and he seemed at last to acquire a tolerance for the digitalis. From December the 16th till his discharge on January the 13th, 1911, he was kept under the influence of digitalis, taking as a rule 30 minims of the tincture in the day, and stopping it for a day if nauseated. He kept very well under this treatment, though the heart beat generally 70 or 90 times to the minute; he was able to walk about in comfort, and was fit for work of a light description (see Chart, Fig. 17).

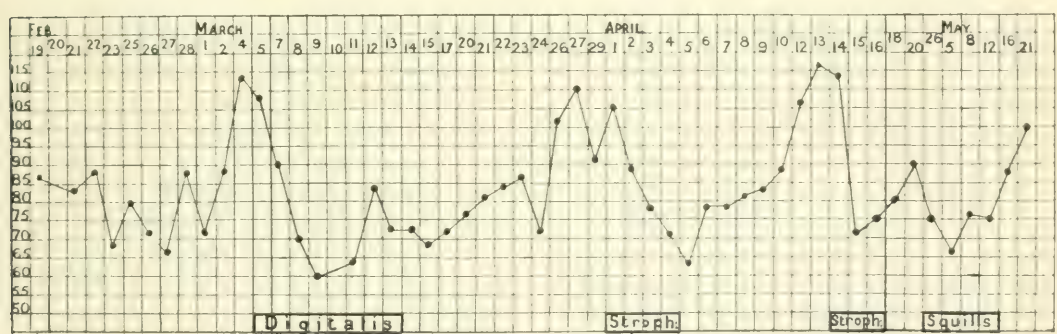


Fig. 17 Chart of CASE 7.

DATE.	DRUG.	PULSE RATE.	URINE.	SIZE.	REMARKS.
Feb.					
19		87	37		Short of breath, no pain, must sit up.
20			43		
21		84	54	1½-7½	Little better, lies down easily on two pillows.
22		88	62		Severe headache, very thirsty, slept fairly.
23		67	75	1-6½	Headache less.
25		80	55	1-6½	Still headache.
26		72	60	1½-6½	Feels better, headache better, slept better.
27		66	78		
28		88	71	1½-5½	Feels better.

DATE.	DRUG.	PULSE RATE.	URINE.	SIZE.	REMARKS.
March.					
1		72	70	1½-5½	Feels better, headache much better.
2		88	72	1-6	Continued improvement, no pain.
4		114	48		
5	Digit. ʒi p.d.	108	74		
7		90	51		
8		70	45		Feels fairly well.
9		60	65		Feels fairly well.
10			65		Not so well, much throbbing in neck.
11		64	52	1¼-5½	Better, less throbbing, had to sit up two or three times in night on account of throbbing and shortness of breath.
12		84	43		
13	ʒix Digit stopped	72	75		Headache, appetite good.
14		72	40	1¼-5¼	No headache, no appetite.
15		68	62		Feels well, slight appetite.
17		72		1¼-6	Feels better, appetite returned.
20		76	44	1½-5½	Feels fairly well, appetite good.
21		81	36		
22		84	37	1½-6	Not so well, pain fluttering in left breast, some dyspnœa.
23		86	49		
24		72	54	1½-5½	Feels better, easier, less dyspnœa.
26		102	61		
27		110	45		
29		92	29		
April.					
1	Stroph. ʒii p.d.	105	37	1¼-6	Feeling very ill and breathless, heart fluttering and thumping.
2		88	36		
3	ʒvi Stroph. stopped	78	36		Feels better but severe headache at back of head which keeps him awake.
4		71	30	1-5½	Feels very seedy, headache, vomiting and diarrhœa.
5		64	39	1¼-5¼	Fee's better, still a little headache.
6		84	40		Feels better, very little headache.
7		84	68		Feels better, no headache, appetite good, diarrhœa stopped.
8		86		1-5½	Feels better, appetite good.
9		87	46		Fairly well, sleeps better.
10		94	46		
12		106	34	1-6	Breathing easy, heart beating fast and fluttering a lot, slept poorly.
13		116	42		Breathing easy, heart fluttering a lot, slept badly.
14	Stroph. ʒi p.d.	114	32		Heart seems quieter, breathing easier.
15		71	42		beating in neck less troublesome. Diarrhœa.
16	ʒiv Stroph. stopped	75	48		Diarrhœa bad.
17			32		Headache bad, heart feels quite quiet, diarrhœa still persists. Slight abdominal pain.
18		80	42	1¼-5½	Diarrhœa ceased.
19			42		
20		90	38		
23					
26	Squills, ʒi p.d.	75	48		Feels ill.
May.					
5		66	76	1¼-5¼	
8		76	66		Feels well, sleeps well, appetite better.
12	ʒix Squills	75	56	1¼-5½	Very short of breath after exercise.
16	stopped	88	56	1¼-6	Headache severe, heart steadier.
					Feels fairly well, but for headache which is very troublesome, fairly good after exercise.
21		100	49	1-6	Heart thumping a lot. Sleeps badly. Frontal headache still severe.

DATE	DRUG.	PULSE RATE.	REMARKS.
Dec. 1910.			
11	Digit. $\frac{5}{16}$ p.d.		Breathing distressed on slight exertion.
12		80	Breathing less distressed.
13		64	Breathing easier.
14	30 minims. p.d.	68	Much improved.
15		70	
16		80	Breathing not so good as yesterday.
17		74	Breathing little easier.
19		80	
20		90	Breathing same.
21		64	Vomited this morning, headache.
22	30 minims p.d.	72	No further vomiting, headache improved.
28		88	Feels well.
29		90	Feels well.
30		90	Slept badly, throbbing in neck, palpitation, some dyspnoea, had to be propped up with pillows.
31		76	Slept well, feels better.
Jan.			
2		74	Feels well, can walk about and go up flight of stairs without distress.
3		90	Same.
4		80	Same.
5		88	
6		90	Feels well.
7		88	Slept better.
9		84	Feels well able to walk about and go up stairs without distress.
10		78	Same.

CASE 8, male, aged 22 years. Auricular fibrillation. Mitral stenosis. History of chorea. Increased flow of urine, vomiting and decrease in pulse rate after digitalis. Aconitine had no effect on the heart.

Admitted August the 19th, 1910, complaining of weakness and shortness of breath and loss of power of left leg and arm.

History. He had had chorea at six and eight years of age, but there was no history of rheumatism. He had typhoid fever in 1897. For some years he had suffered from shortness of breath and palpitation on exertion, but was able to follow his occupation as a barman. In June, 1910, he suddenly lost consciousness and when he recovered he was unable to move his left arm or left leg. Since this time he had lain in hospitals and was admitted into Mount Vernon Hospital from another hospital.

State on admission. The patient lay flat in bed in comfort. He could move his left arm and leg with difficulty and to a slight extent. He was very short of breath on the slightest exertion. The pulse was 100 per minute and continuously irregular. The heart's dulness lay $1\frac{1}{2}$ and $5\frac{1}{2}$ inches to right and left of the mid-sternal line. At the apex there was a systolic and a diastolic murmur. There was no dropsy.

Treatment and progress. From August the 19th to the 23rd the patient received no treatment and the pulse varied from 100 to 110 per minute.

On the 23rd he was put on aconitine, and though it was carefully pushed it had no effect upon the pulse rate, except at times when it seemed to quicken it. From August the 23rd to September the 6th (when the aconitine was stopped), the pulse rate varied from 84 to 156 beats per minute. After all signs of aconitine effect had gone, he was put on tincture of digitalis, 15 minims four times a day on September the 9th. This was continued till September the 15th when it was reduced to twice a day, as on this and the previous day he had been nauseated and had had headache and vomiting. The drug was stopped on the 16th as the vomiting persisted. The following day he felt much better and could breathe with greater comfort after exertion, and continued in this improved condition till his discharge on September the 21st (see Chart, Fig. 18).

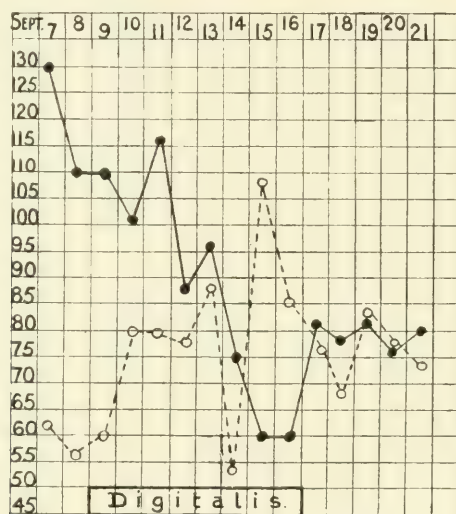


Fig. 18. Chart of CASE 8.

The solid line represents the pulse rate and the interrupted line the urine in ounces.

DATE.	DRUG.	PULSE RATE.	URINE.	REMARKS.
Sept. 7		130	61	
8		110	56	
9	Tr. Digit.	110	60	
10	3i p.d.	102	80	
11		116	80	
12		88	78	
13		96	88	
14		75	54	Feels much better.
15	30 minims.	60	108	Nausea.
16	Digit. stopped.	60	85	Nausea, headache, vomited.
17		82	76	No vomiting, feels much better.
18		78	64	
19		82	83	
20		76	77	
21		80	74	Feels very well.

CASE 9, female, aged 35. Auricular fibrillation. Mitral stenosis. Digitalis produced vomiting, headache and marked slowing of the pulse rate; followed by marked improvement in the general condition. Aconite, strophanthus and squills were also given.

Admitted July the 26th, 1910, complaining of shortness of breath and throbbing of the heart.

History. The patient suffered from "bronchitis" at 25 and had palpitation off and on until admission, she was worse during the two years preceding admission. She had a severe attack of breathlessness four years before admission; there was no history of rheumatism.

State on admission. The patient was very ill and lay propped up in bed. The breathing was rapid and laboured and was aggravated by the slightest movement. The pulse was rapid and irregular, 125 beats per minute. The heart's dulness lay 1 and 5½ inches to right and left of the mid-sternal line. At the apex the sounds were clear but the second was followed by a murmur which filled up the whole diastolic period when the heart was rapid, but when a pause occurred there was a clear interval between the diastolic murmur and the first sound. The liver was three fingers' breadth below the costal margin.

Treatment and progress. The patient being in great distress she was at once put on tincture of digitalis, 15 minims three time a day, and this was continued till the 31st when she had taken 4 drachms; it was stopped as it caused nausea and headache. The patient's breathing was greatly relieved and the pulse rate fell to 61 beats per minute. After stopping the digitalis the disagreeable sensations passed off and the increased liver dulness was almost gone. The pulse rate slightly increased. She was kept at rest in bed till August the 17th and improved considerably. She was then given aconitine which was carefully pushed for 10 days but with no beneficial effect. On September the 2nd she was again given digitalis but was taken ill with some obscure abdominal complaint and it was not continued. In a couple of days she was better and the digitalis was resumed on the 14th, 15 minims were given four times a day. On the 17th she was sick and vomited and the drug was stopped after she had taken 4 drachms. The pulse rate fell to 62-56 beats per minute. After this date the sickness soon subsided and the patient felt better, but the pulse rate increased in frequency and on September the 24th she was given tincture of digitalis, 10 minims three times a day, for five days. This brought on severe headache and nausea with slowing of the pulse to 52, and the drug was then stopped and the pulse rate gradually increased. The patient's pulse rate varied and for some days was between 120 and 130. On October the 16th she was put on tincture of squills, 20 minims four times daily, which was increased on November the 2nd to 30 minims four

times daily. While taking this she suffered a good deal from headache, and though the pulse was not markedly slowed she felt better than she did when taking the digitalis. In November the headache became less severe but on the 14th she suffered from diarrhœa which persisted for four days. This subsided but returned with retching; the drug was stopped on November the 21st. After a few days, the pulse rate increased, varying from 94-120, and on November the 29th she was put on tincture of strophanthus, 20 minims three times daily, but after six doses (2 drachms) the heart slowed to 54, she vomited and had some diarrhœa, and the drug was stopped. After this the pulse rate again increased to 100, and she was put on tincture of digitalis, 15 minims thrice daily on December the 10th. The pulse slowed and the dose was reduced on the 14th to 10 minims. On the 17th she had some headache and was nauseated and the drug was stopped for one day and resumed in 10 minim doses. With this amount she kept fairly well. The drug was occasionally stopped and resumed again until her discharge on January the 11th; at this time she was fairly comfortable when not exerting herself much and was able to go about quietly.

DATE.	DRUG.	PULSE RATE.	URINE.	SIZE.	REMARKS.
July.					
26		125		1 5 $\frac{1}{4}$	Breathing very distressed.
27	Tr. Digit.	106	23		
28	45 minims p.d.	90	30		
29		96	41		
30		80	24 $\frac{1}{2}$		Severe headache and nausea.
31	3iv Digit.	64	31		Severe headache and nausea.
Aug.	stopped				
1		85	37		Severe headache and nausea.
2		60	30		Severe headache and nausea.
3		74	45		Headache gone.
4		90	44		
5		72	36		Feels better, still short of breath.
Sept.					
11		68	35		
12		72	36		
13		68	33		Breathless and palpitation on slightest exertion.
14	Tr. Digit.	78	25		
15	3i p.d.	68	26		
16		74	40		Nausea and severe headache.
17	3iv Digit.	64	12		Vomited.
18	stopped	56			Vomiting.
19		52	12		Feels better, breathing easier on exertion.
20		54	12		
21		69	20		
22		60	30		
23		76	40		Still very short of breath on exertion.
24	Tr. Digit.	87	34		
25	30 minims p.d.	80	20		
26		68	15		
27		67	24		Headache and nausea.
28		60	20		
29	3ii Digit.	52	42		Severe headache and nausea.
30	stopped	60	20		Headache, slight nausea.
Oct.					
1		75	24		Headache better, no nausea.
3		74	22		
6		116	40		
10		120	20		

DATE.	DRUG.	PULSE. RATE.	URINE.	SIZE.	REMARKS.
Oct.					
11		130	32		
12		127	20		
14		96	20		
15		80	20		
16	Tr. Scillæ	80	44		
17	80 minims p.d.	80	40		
22		90	20		
27		80	22		
Nov.					
1	Tr. Scillæ	81	23		Slight headache.
4	3ii p.d.	84	20		
7		70	22		Feels fairly well and can walk about with less distress.
10		88	20		
14		80	40		Diarrhœa.
17		78			Bowels moved five times, feels much better. Bowels moved twice.
18		62	30		Headache, still breathless on slight exertion.
19		60	24		Still headache, pain below left breast.
21	Scillæ stopped	76	20		Retching in night, and this morning, occipital headache.
22		66	16		Retched a little in night, better this morning. Diarrhœa.
23		72	24		No headache, no pain. Diarrhœa.
24		100	34		Feels well.
25		104	24		Cough makes heart beat rapidly.
26		120	10		Cough still troublesome.
28		94	20		Feels better, cough better.
29	Tr. Stroph.	110	30		Heart beating quickly at night for 1½ hours. Cough still troublesome.
30	3i p.d.	74	10		Cough little easier. Heart beating quickly and jumping in night. Kept her awake.
Dec.					
1	Stroph. stopped 3ii	54	20		Vomited three times this morning. Headache. Diarrhœa. Breathing easier but feels ill.
2		56	30	1½-5	Still feels much nausea, no vomiting. Headache. Diarrhœa.
3		74	22		Nausea gone, has headache, diarrhœa.
4		96	19		
4		84	22		Feels better, diarrhœa ceased, "heart quickens at least thing," especially in night.
6		104	20		Feels the same.
7		100	24		Had an aching pain like "toothache" in precordium from 1 to 3 a.m. No sleep. Brought up a few clots of blood last night.
8		104	16		
9		104	24		Breathing short, palpitation in night.
10	Tr. Digit.	92	20		Slept badly.
11	45 minims p.d.		40		
12		86	26		
13		82	20		Very little sleep, slight nausea, headache.
14		62	24		Slept well, feels better, nausea, headache.
15		64	24		Slept very well, has headache, throbbing, slight nausea.
16		64	24		Slept well, still headache, nausea.
17		60	20		Headache severe, feels sick, no vomiting.
18		78	20		Feeling very sick, retching off and on during night, headache.
19	Tr. Digit.	62	16		Feels well, no further retching.
20	30 minims p.d.	64	20	1-6	Slight headache, breathing short on exertion.
21		72	28		Felt faint, headache.
22		70	24		Feels fairly well.
23		68	20		Feels fairly well.

CASE 10. female, aged 44. Auricular fibrillation. Mitral and aortic regurgitation. Digitalis and strophanthus decreased the pulse rate and caused vomiting and headache, followed by marked improvement.

Admitted February the 2nd, 1910, complaining of shortness of breath, palpitation and cough.

History. There was no history of rheumatic fever but at the age of 18-19 she suffered much from pain in her knees, but was able to keep at work. Five years before admission she began to be short of breath and two years before admission she became conscious at times of her heart beating violently and irregularly. Occasionally during the two years previous to admission her legs had swollen. She was married and had had two children.

State on admission. The patient lay propped up in bed, very short of breath on the slightest exertion. Face and lips dusky. There was some oedema of the legs. There were moist crepitations at the bases of the lungs. The respirations were 30 per minute. The pulse was anacrotic and continuously irregular; the rate 98 per minute. The apex beat was in the 5th interspace outside the nipple line. The heart's dulness lay 1 and 5½ inches to right and left of the mid-sternal line. At the apex there was a soft systolic murmur and a soft murmur after the second sound. The murmur was at first low pitched, and at times not perceptible; as she improved, the mitral murmur became permanent, and there were in addition systolic and diastolic aortic murmurs. The liver was slightly enlarged. There was a slight trace of albumen in the urine.

Treatment and progress. The patient was treated for five days with complete rest in bed and so far improved as to be able to lie in bed with comfort, the oedema of the lungs and legs and the enlargement of the liver disappeared. The pulse rate, however, continued to be rapid and she was put on tincture of digitalis, 15 minims four times a day on February the 7th; this was continued till the 11th when she had taken 3¼ drachms. She vomited on the 10th and 11th and the pulse rate fell. By the 14th vomiting had passed off and she felt much better and continued to feel better while the pulse rate kept slow. Gradually she was able to walk about with much less distress. On March the 1st she was put on tincture of strophanthus, 15 minims four times a day, and this was continued till the 31st when the dose was increased to 30 minims four times a day. No discomfort was experienced while she was taking the smaller dose, but on April the 6th she was sick and vomited, and the drug was stopped after she had taken in all 40½ drachms in 37 days. The pulse rate was practically unaffected till April the 4th when it fell considerably in rate. After the nausea passed off, the patient felt much better and continued fairly well till she was discharged on April the 22nd, 1910 (see Chart, Fig. 19).

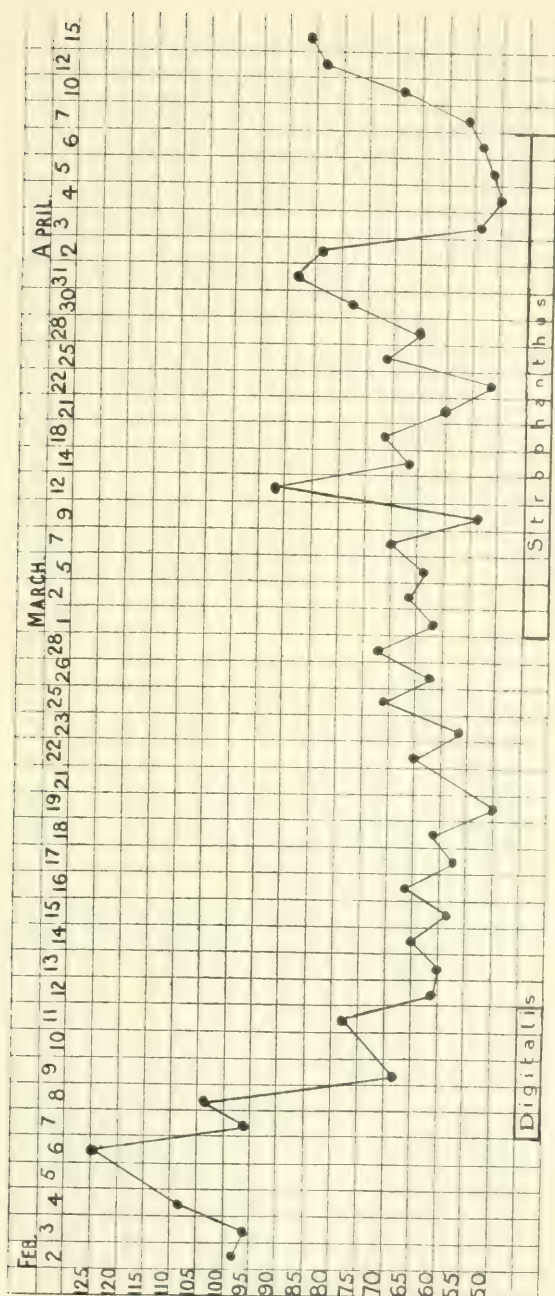


Fig. 19. Chart of C. f. SE 10.

DATE.	DRUG.	PULSE RATE.	RESP.	SIZE.	URINE.	REMARKS.
Feb. 2		98		$\frac{1}{2}$ -4 $\frac{1}{2}$	44	Cough, breathless, palpitation, has to be propped up.
3		96	30		10	
4		108	32		8	Slight cough, dyspnœa, palpitation, sleepless.
5					15	
6		125			25 $\frac{1}{2}$	
7	Tr. Digit. 3i p.d.	96	38	1-5 $\frac{1}{2}$	28	Much more comfortable, can lie with few pillows.
8		104	32		20 $\frac{1}{2}$	
9		69	32		24	Dyspnœa less.
10						Feeling ill, vomited, no appetite, headache bad.
11	3 iii Digit. stopped	78	45	1 4 $\frac{1}{2}$	21	Ill, vomiting.
12		61	34		14	Vomited last night, resting comfortably head only on pillows now.
13		60			8 $\frac{1}{2}$	
14		65	37		15	More comfortable.
15		59	34	1-4 $\frac{3}{4}$	17	Better, breathing better.
16		66	34		11	Feels fairly well.
17		57	34		50	Better, much happier, no complaints.
18		61	26	1-5	17	
19		50	24		18	Feels well, breathing easy.
21					12	Feels well, breathing easy.
22		65	22		16	Feels well, breathing easy. Very distressed after going up flight of stairs.
23		56	36		20	
25		71			24	Feels better. Getting up.
26		63		1-5 $\frac{1}{4}$	14	Still better, headache.
28		72	24		33	Much better.
March. 1	Tr. Stroph. 3i p.d.	62	28		37	
2		66	20		26	Feels well.
5		64	22		25	Feels well.
7		70			26	Dyspnœa after exercise.
9		54	18	$\frac{1}{4}$ -5	25	Can lie flat without dyspnœa, cannot sleep so.
12		92			15	Feels well.
14		66			23	Feels well.
18		72	16		18	Feels well.
21		60	24	1-5 $\frac{1}{2}$	18	Feels well. Slight cough. No dyspnœa.
22		52	30		14	
25		72			18	
28		65			24	
30		78	20		20	Very well, but noticed ankles swollen after walking. Some dyspnœa after exercise and slight œdema of feet.
31		88	20		21	Very well.
April. 2	Tr. Stroph. 3ii p.d.	84	20		27	Slight œdema of feet. Feels well.
4		54	18		17	Feels well. Slight œdema of feet after exercise.
5		50	20	$\frac{1}{5}$ -5	23	Feels well. Slight œdema of feet after exercise.
6	3xlss Stroph. stopped.	52			0	Felt sick all night, only retching.
7		54			15	Still nausea, slight headache. Feels quite well.
8		56			20	
10		68			19	
12		84			22	
15		86			20	
20		92			22	Feels very well.

CASE 11, male, aged 27. Auricular fibrillation. Response to digitalis.

Admitted December the 17th, 1910, complaining of distressing palpitation on exertion.

History. The patient was in good and vigorous health up till June, when he received a blow over the heart in boxing. A few hours after he became conscious of an unpleasant fluttering over the heart. From that time he had been liable to attacks of palpitation, particularly after exertion, sometimes in quietly walking or on standing up. There was no history of rheumatism or of specific infection. He had lived a temperate life, though until a few months before admission he smoked heavily.

State on admission. The patient was tall, spare, muscular and healthy looking. The pulse rate was 85, the rhythm was continuously irregular, with the disorderly rhythm characteristic of auricular fibrillation (Fig. 20).

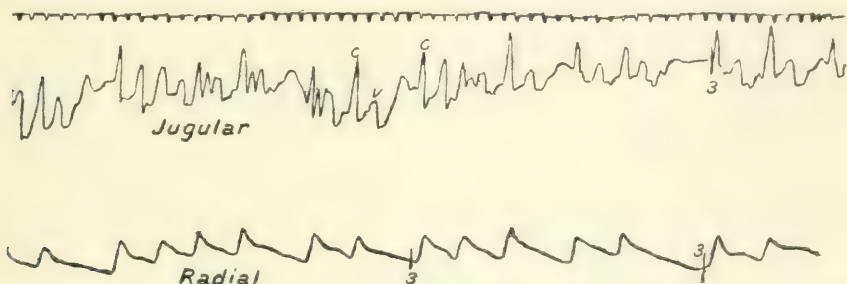


Fig. 20. Tracing of the jugular and radial pulses from CASE 11, before digitalis. The jugular pulse is characteristic of auricular fibrillation. The rate is 75 beats per minute.

The heart's impact was slight and was felt just below the nipple line. The heart's dulness lay $\frac{1}{2}$ and 5 inches to right and left of mid-sternal line. The sounds were clear and free from murmurs, the second sound at the apex being slightly reduplicated. The internal jugular vein was full and pulsated. The pulsation was of the ventricular form and showed the characteristic fibrillation waves.

Treatment and progress. In view of the recent occurrence (June, 1910) of the auricular fibrillation, I felt it might be possible to restore the normal rhythm with complete rest. I had also seen one case revert to the normal rhythm under digitalis, so he was put to bed, and given one granule of Nativelle's digitalin three times a day. His pulse rate speedily fell to 48, and in a few days the heart's size was distinctly less, but there was no sign of a return to the normal rhythm. After nine granules he felt sick and nauseated on December the 22nd; the drug was stopped for three days when he was put on two granules a day which he continued to take till January the 16th. He was allowed to get up and go quietly about on January the 10th. He was carefully

examined on January the 16th. He was feeling much better, was able to go about in comfort and was scarcely troubled with palpitation. The pulse was still irregular, 52 per minute (Fig. 21). His heart's dulness was reduced

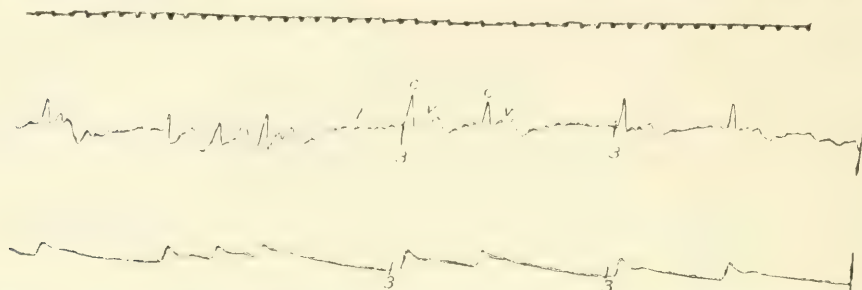


Fig. 21. Tracing of jugular and radial pulses from the same case as Fig. 20, when under the influence of digitalis. The jugular pulse shows well marked *f* waves due to the fibrillating auricle. Rate 52 beats per minute.

to 0 and 4 inches to right and left of the mid-sternal line. He was advised to take one granule per day.

February the 23rd. He had been going about and was able to undertake a considerable amount of effort. He was taking one granule per day. The heart was in the same state as on January the 16th (see Chart, Fig. 22).

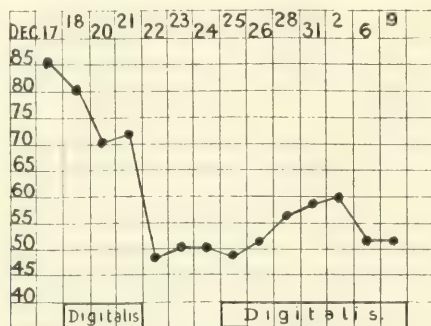


Fig. 22. Chart of CASE 11.

DATE.	DRUG.	PULSE RATE.	REMARKS.
Dec. 17		85	
18	Digit. (3 granules)	80	
20	"	70	
21	"	72	
22	Digit. stopped	48	Nausea.
23		50	Nausea gone.
24		50	
25	Digit. (2 granules)	48	
26	"	52	
28	"	56	
31	"	58	
Jan., 1911.			
2	"	60	
6	"	52	Coupled beats.
9	"	52	

CASE 12, male, aged 53. Auricular fibrillation. Digitalis had a prompt effect in slowing the heart. Aphasic attack during digitalis.

Examined July the 27th, 1910, complaining of shortness of breath and inability to lie down.

History. He had always had a "weak heart". He had been greatly worried during the few years prior to admission, and his heart had been known to be irregular for some years. For some months he had been short of breath, but lately he had felt very much worse and a few days previously to admission had been unable to lie down. He had been treated for some days with repeated injections of strychnine without relief.

State on admission. The patient was sitting up, with laboured breathing and in evident distress. He could not keep still long but had to move about in the endeavour to get relief from the sense of suffocation. The pulse was scarcely perceptible and was very rapid, a tracing was obtained with difficulty and the rate was found to be 160 per minute with occasional slowing for a few beats. The heart's dulness lay 2 inches beyond the nipple line and the sounds were clear and free from murmur.

Treatment and progress. Six granules of digitalin (Nativelle's) per day were prescribed, and after taking six the pulse had fallen to 108. After he had taken ten, the pulse had fallen to 92. The dose was then diminished. Four days after beginning the digitalis he had an aphasic attack during which he could not use nouns. This passed off in a few days. From this date the patient's condition gradually improved. I saw him on October the 22nd. He was taking one granule of digitalin per day and his doctor told me that this dose kept his pulse at a moderate rate. His pulse was continuously irregular, from 76 to 80 beats per minute, and tracings of the jugular showed the characteristic ventricular form of venous pulse with fibrillation waves. He could get about and attend to his business and felt comfortable and well, though moderate exertion caused a good deal of breathlessness.

CASE 13, male, aged 23. Auricular fibrillation. Aortic and mitral disease. Slight fever. Digitalis and strophanthus had little or no effect on the heart.

Carman, admitted April the 11th, 1910, complaining of shortness of breath and palpitation on exertion.

History. The patient had had rheumatic fever at 15 and 21. The last attack of rheumatic fever was in December, 1909, and for this he was kept in bed for 28 weeks, and had not been able to do any work afterwards because of weakness and shortness of breath.

State on admission. The patient, when lying in bed was free from distress; he looked pale but otherwise healthy. The pulse was large, full and collapsing, continuously irregular and beating at about 80 beats per minute. There was marked pulsation of the carotid. The apex was large, diffuse and forcible in the 5th interspace. The heart's dulness lay 1 and 6 inches to right and left of the mid-sternal line. At the apex a rough systolic and a blowing diastolic murmur were heard. In the aortic area, a soft systolic and a diastolic murmur were audible. The systolic murmur was heard over the carotid. The liver was enlarged and pulsated, the border was felt at the level of the umbilicus. There was also some pulsation in the jugulars, and both jugular and liver pulses were of the ventricular form.

Treatment and progress. The patient was kept at rest for a fortnight with little change in his condition. On April the 27th he was put upon tincture of digitalis, 15 minims four times daily. This was continued till May the 9th, when he had taken 12 drachms of the tincture. This had only a slight effect, the pulse slowing down to 72, and causing slight nausea and stomach-ache. The liver was not so large, reaching two fingers below the ribs. He was still very breathless on exertion. On May the 14th he was put on tincture of strophanthus, 30 minims four times a day. This was continued till May the 24th, when he had taken 19 drachms. He vomited on that date and there was slight slowing of the heart's rate, but the liver enlargement, to two fingers breadth below the ribs, persisted. On May the 27th the tincture of strophanthus was resumed, in doses of 30 minims four times a day and continued till June the 1st, when it was intermitted for one day, and then resumed in doses of 30 minims twice daily and continued till June the 15th. From May the 14th till June the 15th he had taken 40 drachms altogether, and though he fancied he felt somewhat better, yet no definite evidence of improvement could be detected. The pulse rate not slowing, and the liver was of the same size and the respiration was laboured and rapid after exertion.

During the whole time of his stay there was a tendency for the temperature to rise above normal, and on June the 6th, he developed a mild attack of rheumatic fever which persisted till the 15th. On that date he was put on salicylate of sodium and the temperature fell while he had the salicylate which was stopped on the 23rd. At his request the patient was discharged, little if any better. He died from heart failure two months after his discharge from the hospital.

DATE.	DRUG.	PULSE RATE.	TEMP.	SIZE.	URINE.	REMARKS.
April. 12		81	97.6	1.6	25	Short of breath and palpitation on exertion.
14		80	98.6		35	
16		86	98		20	
18		74	97.6		22	
20		80	97		32	
24		74	98.6		44	
26		96	98.8	1½-5¼	40	Occipital headache. No palpitation.

DATE.	DRUG.	PULSE RATE.	TEMP.	SIZE.	URINE.	REMARKS.
April						
27	Tinct. Digit.	88			32	
28		96			43	
29		88	97		63	Feels better, still short of breath.
30		90	98		58	
May.						
2		76	98.8		60	Feels rather better.
4		74	97.6		56	
6		64	97.4		49	
7		66	98.4		47	
8		72	98.8		47	Feels very well when quiet. Sleeps well, appetite good.
9	3xii Digit. stopped	90	97.6	1½-5½	40	Nausea and stomachache. Temporal headache.
10		76	99		38	
11			99.6		35	
13		80	99		32	
14	Tinct. Stroph.	74	97.6	1½-6	44	Severe stabbing pain in chest. No sleep last night.
16			98.4		46	Pain bad last night, much better now, worse when lying down.
18		73	98.3	2-5½	35	No pain in chest, breathing easier.
20		70			27	
22		66			48	
24	5xix Stroph. stopped	64	97.2		28	Vomiting to day.
25		66	98		30	
27	Tinct. Stroph.	78	98.4		39	
28		76	98		37	
29		72	99.6		42	
30		78	98.6		43	Feels better, had better night, still some pain in left chest. Very short of breath.
31		84			53	
June.						
1	3ix Stroph. stopped	80	97.8		48	Nausea, short of breath.
2		76	97.2		58	Feeling very well, no pain at all. Very short of breath on exertion.
3	Tinct. Stroph.	88	98.4		33	
5		80	97		47	Feels well, no pain, breathing easier.
6		84			53	
9		74	98.6		38	
10		80	98		30	
12		96	98.4		75	
13		84	99	1½-6½	46	
14		78	99.4		50	
15	5xii Stroph. stopped	84	97		44	Pain in joints since last night, both knees and left wrist swollen and tender.
16	Sod. Sal.	80	97.6		68	Much better, pain all gone from joints though they are still very stiff. Buzzing in ears.
17		63	97.6	1½-6½	21	
18		76	97		32	Feeling very well, still a buzzing in ears.
19		66	98.2		28	
20		76	98		28	
21		80	98		34	
23	Stopped.	96	99		26	No deafness for the last two days. Feeling ill and sick to-day.
24		108	98	2-7	20	Not feeling very well to-day, heart thumps a lot, shaking him about.

CASE 14, male, aged 42. Auricular fibrillation. Mitral disease. Rheumatic history. Slight response to digitalis.

Waterside labourer, (irregular heavy work with much exposure), admitted to the London Hospital, January the 19th, 1911, complaining of shortness of breath and palpitation on exertion.

History. The patient had had rheumatic fever twenty-four years before. In June, 1909 he attended the out-patient department for a pain in his right shoulder, and was then found to have mitral incompetence. The pulse was regular at the time of his discharge in January, 1910. In February, 1910 he fell overboard and was nearly drowned, and the next day he was distressed with palpitation and shortness of breath. He was admitted as an indoor patient on March the 2nd, when his pulse was very irregular. He was discharged to out-patients on March the 16th, his pulse remaining irregular. He had been in attendance as an out patient till his re-admission on January the 19th, 1911. He had been unable to work, being very short of breath and easily upset by excitement.

State on admission. The patient lay comfortably in bed, and was free from distress while quiet. He looked healthy. The pulse was continuously irregular, 70 beats per minute. The heart's dullness lay $\frac{1}{2}$ and 5 inches to right and left of the mid-sternal line. There was a systolic mitral murmur, and a reduplicated second sound. He was breathless on the slightest exertion, such as going up a flight of stairs.

Treatment and progress. He was kept at rest in bed for four days and on January the 24th he was put on tincture of digitalis, 20 minims three times daily, and this was continued till January the 30th, when he vomited. He had taken 5 drachms and 40 minims. There was no effect on the pulse rate, except on the day upon which he vomited, when it fell to 52 beats per minute. There was little change in his condition though he could undertake effort with less distress. After ten days the patient was put on tincture of digitalis, 30 minims per day, and kept on this almost continuously till April the 3rd, when he was greatly improved and able to do light work (see Chart, Fig. 23).

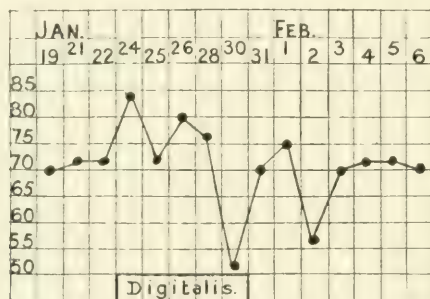


Fig. 23. Chart of CASE 14.

DATE.	DRUG.	PULSE RATE.	URINE.	REMARKS.
Jan. 19		70	20	Comfortable, slight throbbing in precordial region at times.
20			22	
21		72	32	
22		72	52	

DATE	DRUG.	PULSE RATE.	URINE.	REMARKS.
Jan.				
23			60	
24	Tinct. Digit.	84	60	
25	5i p.d.	72	32	
26		80	66	Quite comfortable.
27			44	
28		76	46	Slight pain and throbbing at apex.
29			32	Headache.
30	3v Digit.	52	30	Vomited three times.
31	stopped	70	14	Vomited.
Feb.				
1		75	46	Some headache, sleeps very well.
2		56	46	Feels well.
3		70	40	Feels well.
4		72	56	Headache.
5		72	48	Feels well.
6		70		Can undertake effort with less distress.

CASE 15, male, aged 67. Auricular fibrillation. Senile. Digitalis had only a slight and transient effect on the heart rate.

Admitted October the 13th, 1910, complaining of pains over left chest and shortness of breath.

History. On the whole he had always enjoyed good health. He had had small-pox at 30 years of age and gout at 37 years. Thirteen years before admission he noticed that pain in the chest and shortness of breath came on with exertion and these symptoms continued more or less until admission. He had also suffered from severe attacks of pain in the chest, characteristic of angina pectoris, but there had been no recent attack of pain though he had been very short of breath on exertion. He sometimes had a fluttering feeling over the heart.

State on admission. The patient was a stout ruddy faced man; he lay in bed without distress. The pulse was continuously irregular, 76 per minute, with the disorderly rhythm characteristic of auricular fibrillation. The chest was emphysematous, and it was impossible to percuss the heart limits with accuracy. The sounds were clear and free from murmurs.

Treatment and progress. The patient was kept at rest in bed, and during the first few days he was conscious of attacks during which there was a fluttering sensation over the heart. They were not observed by us and no notes were taken of the action of the heart during attacks. They gradually subsided and the patient improved in strength. He was put on tincture of digitalis, 20 minims thrice daily, on November the 23rd, and this was continued till the 30th when he had taken 7 drachms. It produced nausea and headache and for one day the pulse rate fell slightly in rate. The day after the drug was stopped he felt well and was discharged from the hospital on December

the 3rd decidedly better and less short of breath on exertion. The long rest was probably the chief agent in restoring his strength (see Chart, Fig. 24).

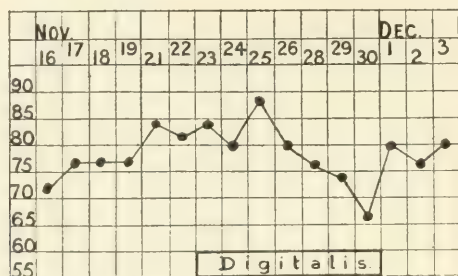


Fig. 24. Chart of CASE 15.

DATE.	DRUG.	PULSE RATE.	URINE.	REMARKS.
Nov.				
16		72	65	
17		76	69	
18		76	48	Feels well except for gouty toes.
19		76	67	Pain easier.
21		84	83	Feels well, short of breath on exertion.
22		82	82	Feels well.
23	Tinct. Digit.	84	71	Feels well, appetite good.
24		80	72	Feels well.
25		88	83	Feels well, no headache, appetite good.
26		80	70	Same.
28		76	84	Same.
29		74	76	Feels well, slight headache last night, better this morning.
30	3vii Digit. stopped	66	76	Much retching and nausea. Throbbing frontal headache.
Dec.				
1		80	95	Feels well this morning, no headache.
2		76	80	
3		80	80	Feels very well, less short of breath.

CASE 16, female, aged 32. *Auricular fibrillation. Mitral stenosis. Rheumatic history. Response to digitalis.*

Admitted January the 18th, 1911, complaining of great weakness and shortness of breath.

History. The patient had had rheumatic fever at the age of 16. She had been in hospital for heart trouble two, three, and five years before. Ten weeks before admission she became ill with shortness of breath, and her legs began to swell. She had been in bed twelve days before she came under my care. She was married and had five children.

State on admission. The patient lay propped up in bed, the breathing was laboured. The face was dusky. There was some ascites and the legs were slightly swollen. The pulse rate was rapid and continuously irregular, 90 beats per minute. The heart's dulness lay 0 and 5 inches to the right and

left of the mid-sternal line. The apex beat was in the sixth interspace. There was a systolic murmur at the apex, and another murmur following the second sound and decreasing in intensity. When the heart was rapid, the latter murmur filled the whole interval between the second and first sounds. When the heart was slow, the murmur fell short of the first sound. (This was very evident when the rate decreased under the influence of digitalis.)

Treatment and progress. As the patient had been on small doses of digitalis and strychnine before coming under my care, she was not given any medicine for four days. Her condition did not alter during this time. On January the 22nd she was put on tincture of digitalis, 10 minims every four hours. She showed no improvement until the 25th, when she became much easier and the pulse rate fell. She vomited on the 27th, and the digitalis was stopped after she had taken 5 drachms. From this date she improved greatly and was able to lie lower in bed, on February the 3rd she could lie flat (see Chart, Fig. 25).

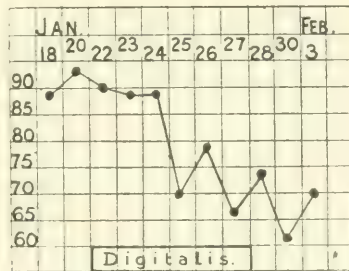


Fig. 25. Chart of CASE 16.

DATE.	DRUG.	PULSE RATE.	REMARKS.
Jan.			
18		89	Lies propped up.
20		94	Cough, breathless. Orthopnoea.
22	Tinct. Digit.	90	Sudden attack of prostration last night, almost pulseless.
23		88	Breathing very distressed and laboured.
24		88	
25		70	Much easier and lies lower.
26		78	
27	3v Digit.	66	Two attacks of vomiting.
28	stopped	74	Comfortable.
30		62	Quite comfortable. Ascites and dropsy gone.
Feb.			
3		70	Comfortable, can lie flat.

CASE 17, female, aged 21. Normal rhythm. Mitral stenosis. Digitalis given on three occasions, on the first it produced vomiting; on the second occasion it was followed by auricular fibrillation for four days, and on the third occasion heart-block occurred.

Admitted October the 5th, 1910, complaining of palpitation, shortness of breath and pain in left side.

History. She had always suffered from shortness of breath and cough. These symptoms had become worse during the year preceding admission, and during the last three or four months she had had attacks of difficult breathing during the night. Palpitation was also readily induced on exertion. There was no history of rheumatism or chorea.

State on admission. The patient lay propped up in bed, the face was healthy looking and had a good colour. The pulse was regular, 96 per minute. (Fig. 26). The apex beat was in the 5th interspace, just outside

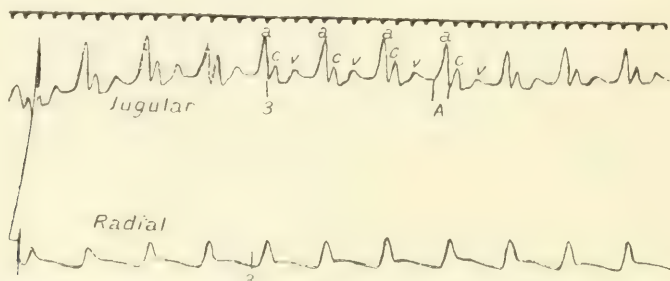


Fig. 26. Tracing of jugular and radial pulses, showing the normal rhythm before the administration of digitalis (CASE 17).

the nipple line. There was a long thrill at the apex during the diastole of the heart. The heart's dulness lay $1\frac{1}{2}$ and 5 inches to right and left of the mid-sternal line. The first sound was sharp and clear: it was preceded by a long crescendo murmur. (When the heart became slower, a diastolic murmur was also heard at the apex.)

Treatment and progress. The patient was kept at rest for 13 days but did not make much improvement. On October the 18th she was given tincture of digitalis, 20 minims three times a day, and this was continued till the 25th when she had taken 7 drachms. While taking it she felt better until the 24th, when she vomited and suffered from headache. The vomiting ceased as soon as the digitalis was stopped and in a few days the headache was better but otherwise there was not much improvement. She continued to suffer from shortness of breath and palpitation on the slightest exertion and on November the 1st she was put on bromide of ammonium, 15 grains three times a day for a week, with no apparent benefit. She was again put on tincture of digitalis, 20 minims three times a day on November the 10th, and this was continued till the 17th when she had taken 7 drachms. She vomited and had headache and on this date a remarkable change took place in the heart's rate and rhythm. Hitherto it had been perfectly regular and rather rapid, sometimes over 100, but on the 17th it became irregular and slow, at a rate of 56 per minute. The presystolic murmur had gone and only a soft diastolic murmur was heard at the apex; and a silence preceded the first sound.

When the intervals between the heart beats were long this silence was very evident. This irregular action continued until the 20th (Fig. 27). On this

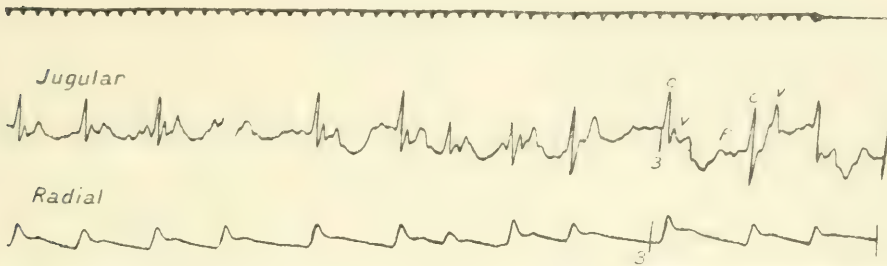


Fig. 27. Tracing of the jugular and auricular pulses during the period of auricular fibrillation induced by digitalis. Note the fibrillation waves *f* (CASE 17).

date I visited the patient with Dr. Lewis and we both listened to the heart and commented on the irregularity and on the absence of a presystolic murmur. While we were examining her, the heart suddenly became perfectly regular and increased markedly in rate (110 beats per minute); on listening over the heart the presystolic murmur had returned. The tracings showed the differences in rate and rhythm and the reappearance of the auricular wave in the jugular pulse. After the sickness passed off, the patient felt much better and exertion did not cause much distress. On December the 9th,

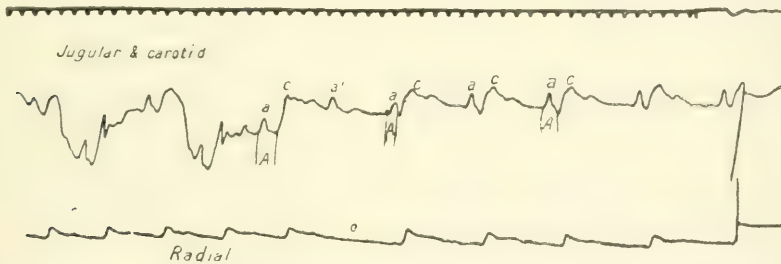


Fig. 28. Tracing of a pulse in the neck and of the radial pulse showing a variation in the *a-c* interval (*A*), and the dropping out of a radial beat at *o* due to partial heart-block. Note the shortening of the space *A* after the pause in the radial and the increase of the space *A* before and after the pause (CASE 17).

she was given digitalis, 20 minims thrice daily; this was continued till the 10th when she had taken 7 drachms. The pulse rate remained unaltered, but a marked sinus irregularity developed. This irregularity was still present on the 17th, and the interval between *a* and *c* sometimes varied, becoming greater during the period when the heart's rate increased; sometimes a ventricular beat dropped out (see Fig. 28). (See Chart, Fig. 29).

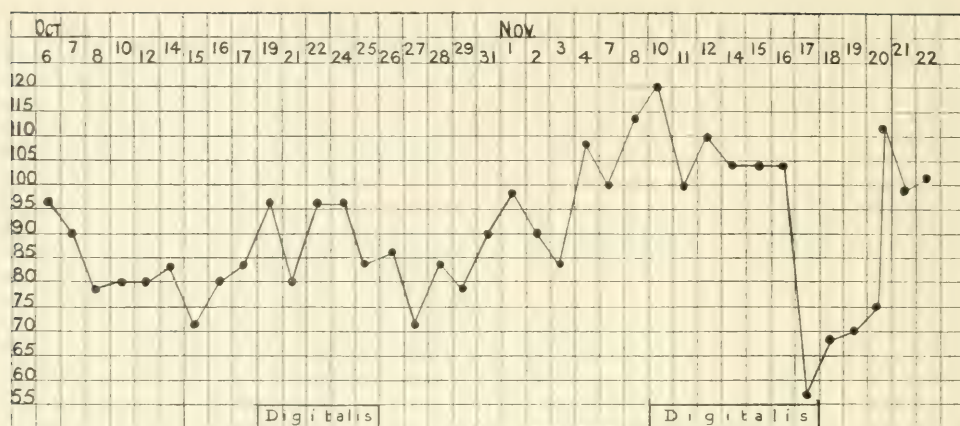


Fig. 29. Chart of CASE 17. From November the 17th to November the 20th the auricles were fibrillating.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	URINE.	SIZE.	REMARKS.
Oct.						
6		96			1½-5	
7		90	135	20		Dyspnœa, palpitation.
8		78	130	40		
10		80		52		Palpitation last night and this afternoon.
12		80		20		Palpitation for 1½ hours in night.
14		84		25		No palpitation for two nights, breathing short on slight exertion.
15		72				
16		80		46		
17		84		40		
18	Tr. Digit.			40		
19	5i p.d.	96		20		Feels well, short of breath on slight movement.
21		80		20		Feels well.
22		96		23		Feels heart thumping, some palpitation.
24		96		20		Vomited yesterday, headache, throbbing.
25	5vii Digit stopped	84		42		Vomited.
26		86		34		No vomiting, nausea.
27		72		32		Slight headache, otherwise better.
28		84		42		Slight headache, heart thumping in night.
29		78		44		Slight headache.
31		90	116	40		Last night palpitation and shortness of breath.
Nov.						
1		98	120	40		Still shortness of breath, no palpitation.
2		90	112	40		Still shortness of breath, no palpitation.
3		84	118	36		Still shortness of breath.
4		108	118	40		Still short of breath.
7		100	110	50		Very short of breath yesterday. Sleep disturbed by bad breathing.
8		114		54		Short of breath.
10	Tr. Digit	120	112	40		Breathing worse, thumping of heart.
11	5i p.d.	100	112	36		Frontal headache.
12		110	120	24		No headache, breathing better.
13			110	34		
14		104	106	30		Feels sick, frontal headache, breathing no better.
15		104	102	36		Feels sick, headache, appetite poor.
16		104	100	15	1½-5	Feels sick, no headache, appetite poor.
17	3vii Digit stopped	56	94	12		Vomited four times in night, headache.

DATE.	DRUG.	PULSE	BLOOD	URINE.	SIZE.	REMARKS.
Nov. 18		RATE. 68	PRESSURE. 118	16		Retching through night, vomited this morning, feels very weak, headache. Breathing a little better.
19		70	120	10	1½-5	Vomited in night, retching frequent, headache better, still some headache.
20		75	110	20		No vomiting, bad headache.
21		98	130	22		Feels well, no headache or nausea, appetite fair.

CASE 18, male, aged 23. Normal rhythm. Mitral stenosis. Digitalis caused heart-block. Death from suffocative oedema of the lungs. P.M. report.

Admitted November the 4th, 1910, complaining of shortness of breath, palpitation and occasional spitting of blood.

History. In childhood the patient had suffered from scarlet fever and measles, but there was no history of rheumatism. Six years before admission he had coughed up some blood and he then noticed he was rather short of breath and suffered from palpitation. The breathlessness and palpitation had become very much worse during the few months prior to admission, so that he had not been able to follow his work as a labourer.

State on admission. The patient was quite comfortable when at rest and could lie flat in bed. The pulse was 92 beats per minute, and was regular, save for the occurrence of occasional extrasystoles. The apex beat was in the 5th interspace. The heart's dulness lay $\frac{3}{4}$ and $4\frac{1}{4}$ inches to right and left of the mid-sternal line. At the apex there was a rough presystolic murmur running up to the first sound, and a murmur following the second sound, so that the whole pause between the two sounds was filled by the two murmurs. There was no dropsy, and the urine was free from albumen.

Treatment and progress. The patient was kept at rest for nine days, and no drug was given. There was a slight irregular rise in temperature during the first week. The pulse rate varied from 108 to 76, the more rapid rate occurring when there was a rise of temperature. On November the 14th he was put on tincture of digitalis, 20 minims thrice daily, and this was continued till the 22nd, when he had taken $7\frac{1}{2}$ drachms. He vomited several times on the 21st and 22nd, and the drug was stopped. The pulse rate fell to 66 beats per minute, and on one occasion, when the pulse slowed after exertion, occasional pauses were detected in the heart's action, which a tracing showed to be due to partial heart block (Fig. 30). There was a slight increase in the a-c interval when he was under the influence of the digitalis. Before taking the digitalis the extrasystoles had disappeared, and while taking the drug, the patient felt very well. This improvement, however, had set in before the digitalis was given. After the digitalis was stopped, the vomiting ceased and the patient continued to feel well so long as he kept quiet.

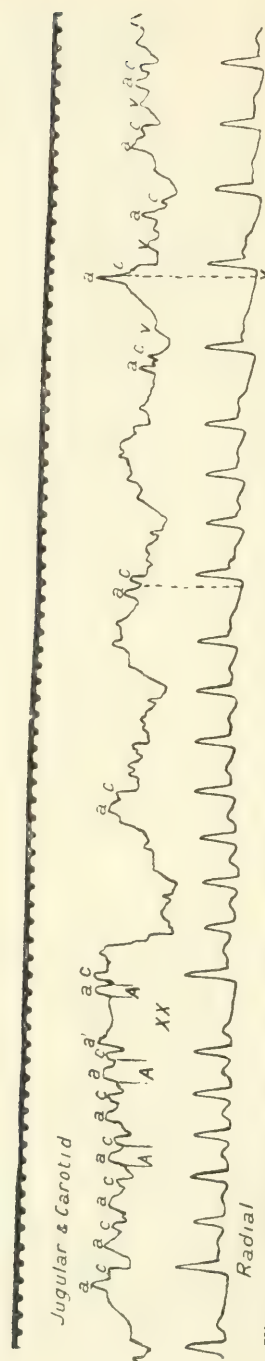


Fig. 30. Shows an irregularity due to phasic variations in the heart's rate. The rate is continuously varying, and during the slow phases the ventricular systole occasionally occurs independently of the auricular systole, as at X, where the high wave *a* appears at the beginning of ventricular systole. The increased height of this wave is due to the auricle contracting at the same time as the ventricle, so that the contents of the auricle are forced back into the veins. At XX the wave *a'* is not followed by a carotid wave (*c*) nor by a radial pulse beat. The *a-c* interval (space *A*) before *a'* is greater than the normal and greater than the *a-c* interval following. The increase in the length of the *a-c* interval and the falling out of the ventricular systole after *a* is due to partial heart-block from digitalis.

On the night of November the 30th he began to cough up large quantities of a pink frothy expectoration, which seemed to well out of his mouth. This continued for some hours, and then subsided. All the next day he continued to cough up some of the same material and felt very weak and ill. The lungs showed numerous fine crepitations all over. The pulse was full and rapid, and he sank and died soon after midnight on December the 1st (see Chart, Fig. 31).

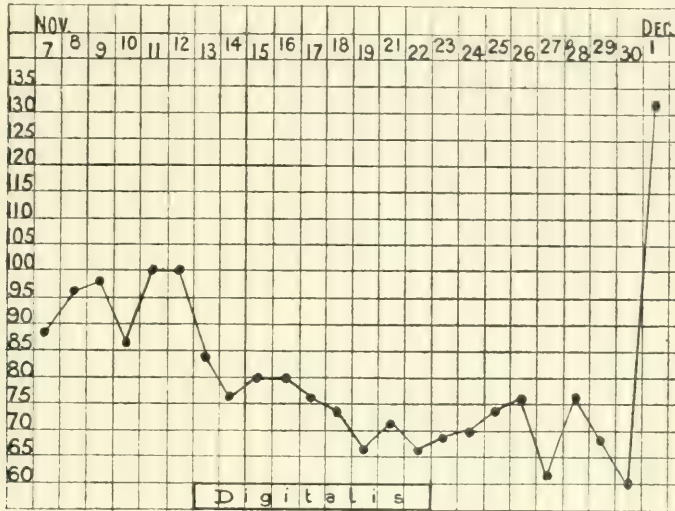


Fig. 31. Chart of CASE 18.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	URINE.	SIZE.	REMARKS.
Nov. 7		88			3-4 1/4	Sputum shows a few blood streaks.
8		96	116			Has some palpitation.
9		98	116	36		A little palpitation.
10		86	128	41		Has some cough.
11		100	112	63		Coughing attacks in morning.
12		100	110	62		Cough troublesome in night.
13		84	106	48		
14	Tinct. Digit.	76	112	35		Feels well.
15	5i p.d.	80	110	54		Feels well.
16		80	112	65	1 1/4-4 1/4	Feels well.
17		76	110	79		Feels well.
18		74	102	77		Feels well.
19		66	120	52		Feels well.
21		72	112	53		Vomited this morning, no headache.
22	5vii Digit.	66	112	45		Vomited four times in night.
23	stopped	68	110	41		No further vomiting, no appetite, no headache.
24		70	110	34		Appetite better, feels well.
25		74	110	40		
26		76	100	33		Feels better.
27		62				
28		76		53		Feels well.
29		68	100	71		Feels well, no cough.
30		60	100	56		
Dec. 1		132				Coughing up large quantities of blood stained froth.
2						Died.

Post mortem report by Professor Woodhead.

Right lung. Weight 2 lbs. 4 oz.. Some old adhesions of upper and middle lobe : slight adhesions between lower and middle lobe at base ; no recent pleurisy. Intense congestion throughout, with slight oedema and some consolidation. Peculiar brick-red colour. Clots in branches of pulmonary artery.

Left lung. Weight 1 lb. 10 oz.. The glands at root of left lung enormously enlarged and greatly congested ; calcareous gland at root of lung. Intense congestion with some oedema as in other lung, more marked at base. Evidence of old pleurisy with a definite pigmented cicatrix near the apex of the lung. Well-marked adhesions between the two lobes. Cicatrix extends for a considerable distance into the lung, and is continuous with thickened pleura on surface ; evidently an old and healed tuberculous cavity, distinctly localised and associated with calcareous gland at root of lung.

Right kidney. Weight $5\frac{3}{4}$ oz.. Capsule slightly adherent. Surface somewhat mottled, congested. At one point capsule firmly adherent to a depressed area of kidney, old infarction (?). Malpighian bodies fairly distinctly marked, some congestion of both cortex and medulla, vessels fairly patent, cortex if anything slightly thinned.

Spleen, (portion of). Evidently from enlarged spleen, soft, pulpy and congested. Malpighian bodies somewhat paler, standing out prominently with deeper coloured centre, pulp still more deeply coloured. Resembles a fibroid spleen. Depressions as though there had been infarction at two or three points.

Thyroid enlarged ; parathyroid much enlarged.

Heart. Weight 13 oz. Adhesion of the pericardium over the left auricle. Glands all round the heart and around trachea enormously enlarged and greatly congested. Great congestion of tracheal mucous membrane. Post-mortem clots in both auricles.

Right ventricle considerably dilated.

Left ventricle. Wall very flaccid and flabby, pale. Ante-mortem clot in right ventricle beginning at apex and extending up into right auricular appendix. Pale endocardium, slight mottling, fatty (?). Adhesion of margins of mitral valve, marked fibrous tissue extending into musculi papillares.

Left auricle. All round base of mitral valve sharp calcareous points in thickened fibroid ring, thickened endocardium thrown into folds and very opaque. Muscle wall probably hypertrophied.

Right auricle. Wall comparatively thick as compared with left, only slight thickening of tricuspid cusps, no incompetence. Slight thickening of endocardium. Pectinate muscles quite distinct, consisting of bands with clear spaces between. Very firm white clot in auricular appendix.

Sinus of coronary vein very large and well-marked. Very slight thickening of cusps of the aortic valve. Thickening of margins of coronary cusps, slight thickening of wall of coronary arteries which, however, are quite patent and of considerable size. A good deal of fat in A-V groove.

CASE 19, female, aged 30. Normal rhythm. Mitral stenosis. Rheumatic history. Digitalis and strophanthus produced vomiting and slightly decreased the pulse rate.

Seamstress, admitted October the 21st, 1909, complaining of breathlessness on the slightest exertion.

History. The patient had had rheumatic fever at 14, 17 and 21 years of age, and hæmoptysis in September, 1907. In September, 1908 she had a sudden loss of consciousness, followed by a right hemiplegia; from this she gradually recovered and was fairly well till three weeks before admission, when she became very short of breath.

State on admission. The patient was a small puny woman, the face was somewhat dusky. The pulse was regular and varied from 50-70 beats per minute. The apex beat was in the 6th interspace, $\frac{3}{4}$ inch outside the nipple line and forcible. There was a long crescendo murmur running up to the first sound at the apex and the second sound was reduplicated. At times a short whiff was heard after the second sound at the apex.

Treatment and progress. The patient was kept at rest with no special treatment for 18 days. There was little improvement in her condition, her chief complaint being breathlessness on exertion. On November the 8th she was put on tincture of digitalis, 15 minims thrice daily, and this was continued till November the 15th when she had taken 5 drachms. Her pulse rate fell to between 42 and 50. She was very sick and vomited. After the drug was stopped she felt fairly comfortable but was still breathless on exertion. She had digitalis on two other occasions from November the 27th to December the 1st (4 drachms) and from January the 13th to the 19th (6 drachms). In both instances the medicine produced vomiting, on the last occasion headache also, and the pulse rate fell to between 60 and 50.

On February the 10th she was put on tincture of strophanthus, 15 minims four times a day, and this was continued till the 18th when she had taken 7 drachms. This produced diarrhœa and nausea, and the pulse rate fell to 44 after the diarrhœa stopped.

There was a gradual improvement in her condition, in so far as she could undertake effort with less distress, till her discharge on March the 2nd. It is doubtful whether the drugs had any good effect, the rest alone being the probable cause of the improvement (see Chart, Fig. 32).

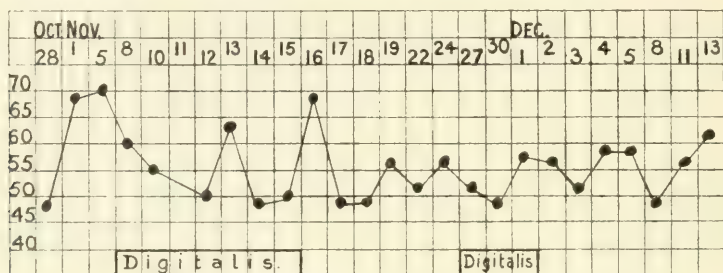


Fig. 32. Chart of CASE 19.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	SIZE.	URINE.	REMARKS.
Oct.						
10		84				
24		52			28	
28		48			28	
Nov.						
1		68			40	
5		70			27	
8	Tr. Digit.	60			35	
10	45 minims p.d.	55	98		32	
11			90		18	Vomited once this morning, sleeps badly.
12		50	90	$\frac{1}{2}$ 5 $\frac{1}{2}$	22	
13		64			34	
14		48			47	
15		50	100		31	
16	5v Digit. stopped	68				Vomited.
17		48	90		18	Comfortable, but sleeps poorly.
18		48	90		25	
19		56	98		24	Feels better.
22		52			28	Feels well.
24		56	92		46	
27	Tr. Digit.	52		$\frac{3}{4}$ 5	40	
30	5i p.d.	48	96		36	
Dec.						
1	5iv Digit. stopped	57	92		32	Feels sick, vomited.
2		56			26	
3		51	96	$\frac{3}{4}$ 4 $\frac{3}{4}$	25	Feels better.
4		58	96		26	
5		58			58	
8		48			28	Feels well.
11		56	92		34	
13		62			40	
Jan.						
2		58	92		32	
3			90		38	
6		72			40	
9		96			36	
11		54	92	$\frac{1}{2}$ 4 $\frac{3}{4}$	10	
13	Tr. Digit. 5i p.d.	44	92		34	

DATE.	DRUG.	PULSE.	BLOOD RATE. PRESSURE.	SIZE.	URINE.	REMARKS.
Jan. 14		72	88		36	Easily becomes breathless.
17		48	92		40	Vomited at 6 a.m., feels well but thinks she is rather more breathless.
18		44	88	$\frac{1}{2}$ -4 $\frac{1}{2}$	40	Feels better. No more sickness.
19	5vi Digit. stopped				8	Been vomiting, severe frontal headache.
20		46			15	Feels very seedy, menstruating.
23		48			34	Feels well. Less breathless after exertion.
28		48		$\frac{1}{2}$ -4 $\frac{1}{2}$	27	Feels well.
30		72			37	Feels very well.
Feb. 9		68	96	$\frac{1}{2}$ -4 $\frac{1}{2}$	34	Very breathless after exertion.
10	Stroph. 3i p.d.				36	
12		60		$\frac{1}{2}$ -4	25	Less breathless after exertion.
14		52			25	Feels very well.
16		46	96		24	
17		72	106	$\frac{3}{4}$ -4 $\frac{1}{2}$	13	Feels better. Diarrhœa to-day.
18	3vii Stroph. stopped	60			17	Diarrhœa severe yesterday (12 motions), less severe to-day. Slight headache, nausea, otherwise fairly well.
21		44			23	Feels well now, felt quite well after exercise.
23		44	90		32	
25		62			40	
26		72			22	Feels well.
28		60	102		26	
March. 2		52				Feels well.

CASE 20, female, aged 34. Normal rhythm. Mitral stenosis. Digitalis had no apparent effect on the heart or blood pressure.

Admitted April the 11th, 1910, complaining of shortness of breath upon the slightest exertion and pain in the left chest.

History. The patient was quite well till two years before admission, but had suffered from weakness, breathlessness and pain in the chest during the two years. She had never had rheumatism or any serious illness. She was married and had had five children.

State on admission. The patient was a small woman and well nourished, the cheeks were flushed and slightly dusky. She could lie comfortably on a low pillow but was short of breath on exertion. The pulse was regular, 64 beats per minute, and the blood pressure was 102 mm. Hg. The apex beat was in the 6th interspace outside the nipple line. The heart's dulness lay 0 and 4 $\frac{1}{2}$ inches to right and left of the mid-sternal line. At the apex there was a presystolic murmur running up to the first sound. The second sound was reduplicated. At the aortic area the sounds were clear.

Treatment and progress. The patient was kept at rest without further treatment till the 16th, when she was put on tincture of digitalis, 15 minims four times a day; this was continued till the 20th. The notes of the results

of the exhibition of digitalis are unfortunately limited to the pulse rate and urine secretion, and these show no definite effects from the drug. She undoubtedly felt better afterwards and was again placed on tincture of digitalis, 15 minims four times a day on May the 15th, and it was continued till the 20th. On this date she was sick and vomited, and suffered much from headache. This symptom had disappeared on the following day, and after this she felt very well, although there was no appreciable effect upon the heart rate or rhythm, except for the occurrence of extrasystoles after exertion. She was discharged from the hospital on May the 23rd very greatly improved (see Chart, Fig. 33).

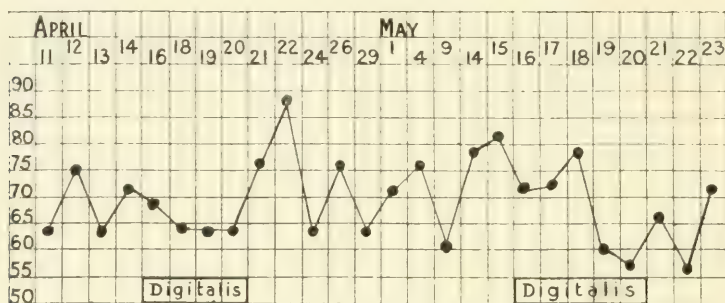


Fig. 33. Chart of CASE 20.

DATE.	DRUG.	PULSE RATE	BLOOD PRESSURE.	SIZE.	URINE.	REMARKS.
April.						
11		64	102	-4½	26	Short of breath, cough troublesome.
12		75			16	
13		46			16	Little better.
14		72			10	
16	Tr. Digit. ̄i p.d.	68			38	
18		64			18	Feels better.
19		64			18	
20	̄v Digit. stopped	64	112		26	
21		76			28	
22		88			18	
24		64			18	
26		76			20	
29		64			28	
May.						
1		72			12	
4		76			24	
9		60			14	
14		78			20	
15		81			14	
16	Tr. Digit. ̄i p.d.	72	128		20	Feels well.
17		73			19	
18		78			19	
19		60	112	-4½	15	Feels very well.
20	̄v Digit. stopped	57	106		4	Feels sick, vomited in the night. Frontal headache.
21		66	116		14	Feels quite well, appetite good. Headache gone.
22		56			7	
23		72	104		10	Feels quite well.

CASE 21, male, aged 36. Normal rhythm. Mitral stenosis. Rheumatic history. Digitalis produced vomiting and partial heart-block, but did not materially slow the pulse.

Admitted August the 4th, 1910, complaining of shortness of breath and over left chest.

History. He had had three attacks of rheumatic fever between the ages of 8 and 20, the fourth attack being in 1906. After each attack pain in the left chest was felt for some time. From February, 1910, he had suffered much from shortness of breath and pain in the chest, especially on exertion.

State on admission. The patient was healthy looking, the pulse regular, the apex beat being in the 5th interspace. The heart's dulness lay 0 and 3_s inches to right and left of mid-sternal line. At the apex there was a short rough murmur terminating in a snapping first sound. (At times this murmur was represented by a distinct sound of a soft character).

Treatment and progress. When at rest the patient suffered from no discomfort, but very slight effort induced the pain and breathlessness. For 10 days he was kept at rest and during this time his pulse rate varied from 74 to 110 beats per minute and his blood pressure from 110 to 122 mm. Hg.. He was then put on aconitine, but although the drug was pushed till distinct symptoms were produced, such as dryness in the throat, the pulse rate kept up, and increased in rate on the whole, while the blood pressure fluctuated

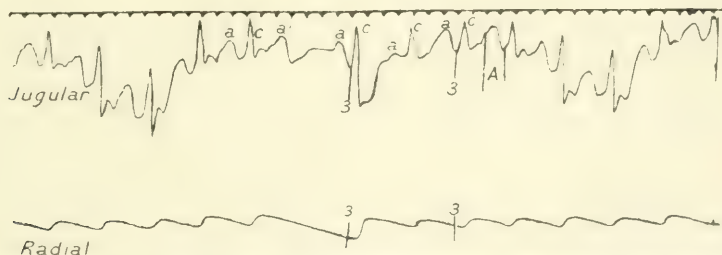


Fig. 34. Shows a pause in the radial and the absence of a c wave after the auricular wave a due to partial heart-block. The a-c interval (space A) is increased.

between 114 and 140. He had been taking aconitine from August the 18th to September the 6th. He remained without drugs till September the 10th when he was given tincture of digitalis four times a day till September the 16th; he had then taken 5½ drachms. On September the 15th he vomited but there was no effect on the heart's rate nor on the blood pressure. On the 16th the pulse was occasionally intermittent; simultaneous tracings of the jugular and radial pulses showed a partial heart block (Fig. 34.). It

was not detected after this date. The patient was discharged feeling much better, in that he could go upstairs with comfort, but a month after he appeared at the out-patient department with a recurrence of the pain and distress in breathing.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	URINE.	REMARKS.
Sept. 6		100	130	54	
7		104	134	68	
8		106	130	70	
9		100	116	60	
10	Tr. Digit.	100	124	72	
11	3 i p.d.	102	128	72	
12		90	120	82	
13		96	100	74	
14		94	108	59	Vomited.
15		100	108	72	Vomited violently.
16	3vss Digit. stopped	96	120	72	Headache, pulse intermittent, no nausea. (partial heart-block.)
17		98	124	62	Better.
18		96	128	67	
19		94	126	70	
20		94	124	70	
21		98	125	68	Feels much better, can go upstairs with less distress.

CASE 22, female, aged 32. Normal rhythm. Mitral stenosis. Rheumatic history. Digitalis had no effect upon the heart.

Married, admitted November the 9th, 1910, complaining of pain in the chest and shortness of breath.

History. She had rheumatic fever at 9, 18 and 31 years of age. She had had five children and was five months pregnant. She had been short of breath for a long while, but had gone through her pregnancies and confinements with very little trouble. During the three weeks prior to admission her breathlessness had increased.

State on admission. The patient was well nourished and healthy looking. She could walk about quietly without distress, but breathlessness was easily induced on exertion. The pulse was regular. The heart's dulness lay $1\frac{1}{2}$ and 5 inches to right and left of the mid-sternal line. The apex beat was in the 5th interspace. There was a systolic murmur, loudest at the apex and conducted into the axilla. There was also a presystolic murmur running up to the first sound and a short murmur following the second sound. The last two murmurs were only heard over a limited area around the apex.

Treatment and progress. The patient was kept at rest and given no drug for a week after admission. The murmurs were found to vary, the pre-systolic and diastolic often disappearing when resting but usually reappearing

after exertion. On November the 16th she was given 15 minims tincture of digitalis three time a day and this was continued till the 23rd, when she had taken 5 drachms. It was stopped because it caused severe headache : there was no effect on the pulse rate or the blood pressure. She felt very well after the headache passed away and was able to undertake effort with much less distress. She was discharged on December the 6th feeling very well.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	SIZE.	URINE.	REMARKS.
Nov.						
11		86	114		11	
12		88			40	
13		90			15	
14		88			30	
15		86		1½-5	12	
16	Tr. Digit.	80	98		28	
17	45 m. p.d.	80	98		10	
18		88	102		42	Feels better in every way.
19		88	106	1½-5	12	
20		90			10	
21		90			24	
22		75			46	Headache, otherwise feels well.
23	5v Digit. stopped	85			22	Headache severe, constipation.
24		80	100	¾-5	38	
25		88				
26		72				
Dec.						
2		80	106		56	Feeling very well for past four days. Headache disappeared when bowels well opened.
4		84	102		58	Feels well.
5		80			60	
6						Been up, feels very well.

CASE 23, female, aged 50. Normal rhythm. Mitral stenosis. Rheumatic history. Numerous extrasystoles and pulsus alternans. Digitalis had no effect upon the heart rate or upon the occurrence of extrasystoles.

Admitted April the 19th, 1910, complaining of great shortness of breath and exhaustion upon the slightest exertion.

History. Rheumatic fever at 9. She was married and had five children. For five years she had been very short of breath, and this had been so bad for the few months preceding admission that she could not lie down in bed. In the night she was sometimes distressed by attacks of breathlessness (cardiac asthma). She had had attacks of faintness and exhaustion, even when resting, for many years but never lost consciousness. There were other attacks which came on every few months: in these she lost consciousness, was convulsed, and passed urine.

State on admission. The patient was well nourished, the face was dusky, and she lay propped up in bed. The pulse was 96 per minute, large and irregular as a result of frequent extrasystoles. After each extrasystole the

pulse alternated. The blood pressure for the large beats was 174 mm. Hg.. The apex of the heart was in the 5th interspace, just outside the nipple line and $4\frac{1}{2}$ inches from mid-sternal line. At the apex there was a systolic murmur and a faint presystolic running up to the first sound. The last murmur was frequently absent.

Treatment and progress. The patient was evidently very distressed on admission; the slightest exertion, such as turning in bed, brought on dyspnœa, and it seemed from her history that the exhaustion arose from attempts to perform her many household duties when the heart was enfeebled. After 10 days rest in bed she had greatly improved. The attacks of cardiac asthma had disappeared and she could turn in bed without dyspnœa. From the 6th to the 13th, she was given iodide of potassium. During that time she took altogether 225 grains, but there was no apparent effect. The extra-systoles continued to be frequent, but the improvement continued so that she felt very comfortable in bed and could walk about without distress. On May the 16th she was given tincture of digitalis, 15 minims three times a day; this was continued till the 20th when she had taken altogether $3\frac{3}{4}$ drachms. On the 20th she vomited and had a good deal of headache. The breathing was easier but the extrasystoles persisted. The digitalis did not affect the pulse rate. On the 21st she felt quite well and there was no headache. The patient continued to improve and was discharged on June the 3rd greatly improved in health, though the extrasystoles were as frequent but the *pulsus alternans* was much less marked (see Chart, Fig. 35).

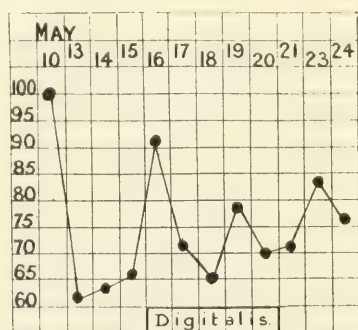


Fig. 35. Chart of CASE 23.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	URINE.	REMARKS.
April 26		96	174	24	Very breathless on slight exertion. Occasional attacks of breathlessness during night.
May 5		72	124	20	
6				25	Feels less breathless. No attacks of breathlessness during night for a week.
8		104		18	

DATE	DRUG.	PULSE RATE.	BLOOD PRESSURE.	URINE.	REMARKS.
May 9		60		20½	
10		100	142	40	
13		62	152	42	Feels very well.
14		64		17	
15		67		17	
16	Tr. Digit.	92	172	34	Feels very well.
17	45 m. p.d.	72		27	
18		65		48	
19		78	156	37	Feels very well.
20	5iii & m. 45	70		18	Vomited this morning, frontal headache, otherwise feels well. Breathing easy.
	Digit. stopped				Feeling quite well again. No headache.
21		72	126	42	
23		84	150	38	Feels quite well.
24		76	136	27	
26				51	
27		66		40½	
30		72	130	36	
31		78		44	
June 6		72	180	22	Feels quite well, no more attacks of breathlessness.

CASE 24, female, aged 24. Normal rhythm. Mitral stenosis. Rheumatic history. Digitalis and squills decreased the heart rate and caused heart-block, sinus irregularity, extrasystoles and "pulsus alternans."

Upholstress, admitted February the 26th, 1910, complaining of shortness of breath and palpitation on the slightest exertion.

History. The patient suffered from scarlet fever in childhood, rheumatic fever at 12, and chorea at 14. She was laid up with weakness and dropsy at 16.

State on admission. She was pale and spare and lay propped up in bed. The pulse was regular at 72 beats per minute. The heart's dulness lay 2 and 5½ inches to right and left of the mid-sternal line. The apex was in the 5th inter-space. There was a diastolic thrill over the apex. At the apex there was a rough presystolic murmur, running up to the first sound, and a soft murmur following the second sound and separated from the presystolic by a brief interval when the rate was slow, but running into it when the rate was rapid. A systolic murmur was heard and was loudest over the middle of the sternum.

Treatment and progress. The patient was kept most of the time in bed for eight days after admission. She improved considerably and at the end of a week she was able to walk up a flight of stairs with less distress. On March the 6th she was put upon tincture of digitalis, 15 minims four times a day, and this was continued till the 18th when she had taken 11¼ drachms. During the time she was on digitalis her condition varied, sometimes she was able to take exercise with little discomfort, at other times she suffered a good deal from breathlessness. About the 14th she began to suffer from headache, which became very severe, and on the 18th vomiting set in and the

digitalis was stopped. Her pulse rate had fallen as low as 40 beats per minute on the 15th, other changes in the rate also appeared, especially after exertion. The heart always beat very fast after exertion, but it fell to

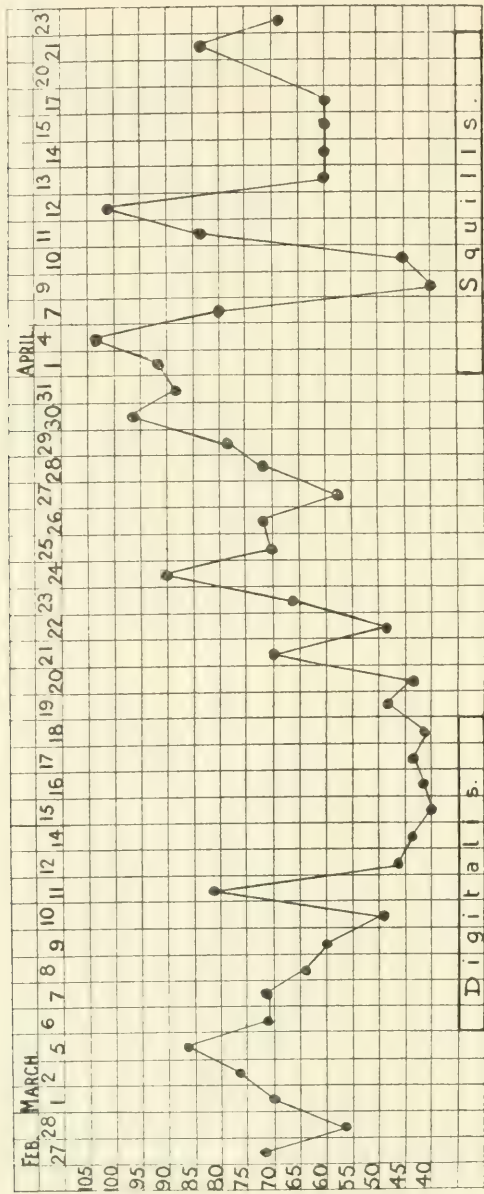


Fig. 36. Chart of CASE 24.

between 40 and 50 beats per minute after three or four minutes. As the pulse became slower after exertion, three forms of irregularity appeared,

namely, sinus irregularity, extrasystoles, and heart-block. The blood pressure showed little change before and after the digitalis. It fluctuated before the drug was given from 95 to 116 mm. Hg.. When the vomiting and headache set in, the blood pressure was 112. A few days after the drug was stopped, it was 118. For a week after the digitalis the patient felt very well. The headache and sickness speedily disappeared, and the patient felt very much better, the breathing being easier after exercise and the appetite improving. The pulse rate then began to increase and the patient was given tincture of squills, 15 minims four times a day. This was continued from April the 1st till the 21st, when the patient had taken 20 drachms. The squills had the same effect as the digitalis in slowing the pulse and improving the patient's condition, and was accompanied by much less headache and digestive disturbance. The heart showed the same reaction after exercise, only the heart-block was more marked.

The patient left the hospital on the 30th much improved and able to resume her work (see Chart, Fig. 36).

(A full description of the irregularities of this patient has been given by Turnbull (*Heart*, 1910-11, II, 15).)

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	SIZE.	URINE.	REMARKS.
Feb.						
27		72			36	Very short of breath.
28		56	114	2-5 $\frac{1}{4}$	14	Feels much better, sleeps well without pillows.
March						
1		70	112	1 $\frac{1}{2}$ -6	24	Feels better, can lie almost flat without distress.
2		76	128	1 $\frac{1}{2}$ -5 $\frac{1}{2}$	32	Feels better.
5		86	130	1 $\frac{1}{2}$ -5 $\frac{1}{4}$	24	Feels better, less breathless.
6	Tinct. Digit. 5i p.d.	72			40	
7		72			30	Feels well, but dyspnoea after exertion.
8		64			40	
9		60	132	1 $\frac{1}{4}$ -5 $\frac{1}{2}$	44	More breathless after exercise.
10		48			56	Not quite so well, heart thumping, slight headache.
11		82			23	Feeling very well.
12		46			56	Feels well. Occasional extrasystoles after exercise.
14		44		1 $\frac{1}{4}$ -5 $\frac{1}{2}$	45	Not feeling quite so well. Marked sinus arrhythmia after exercise. Few extrasystoles.
15		40			29	Feels fairly well, headache this morning.
16		42			33	
17		44			22	Not feeling so well, headache.
18	3xi $\frac{1}{2}$ Digit. stopped	42	116	1 $\frac{1}{4}$ -5 $\frac{1}{2}$	24	Not so well, headache severe. No sleep last night and vomited.
19		48			28	
20		44	132	1 $\frac{1}{4}$ -5 $\frac{1}{2}$	40	Very well, no headache, appetite good. Breathing better than ever before. One auricular impulse blocked. Sinus arrhythmia. Occasional extrasystoles after exercise.
21		70			45	No dyspnoea but some little palpitation after exercise. Sinus arrhythmia more after exercise.
22		48			43	

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	SIZE.	URINE.	REMARKS.
March						
23		66			42½	Sinus arrhythmia, extrasystoles.
24		90		1½-5½		Feels well, slept well. Sinus arrhythmia after exercise.
25		70				
26		72-78				
27		57				
28		72				
29		78				
30		96	114	1½-5¼		Feels well. No dyspnœa after exercise, no sinus arrhythmia.
31		88	124			
April						
1	Tinct. Squills 3i p.d.	92				Not feeling so well, some palpitation and dyspnœa.
4		104		1½-5½		Feels well.
7		80		1½-5½		Not feeling well, low spirited, headache.
8						Feels well.
9		40				Feels quite well,
10		45		1½-5¼		Feels very well.
11		84				Marked sinus arrhythmia after exercise.
12		102				Marked sinus arrhythmia.
13		60				Heart-block.
14		60				Heart-block and irregularities (extra systoles and pulsus alternans) after exercise.
15		60				Heart-block and alternation after exercise.
17		60				Heart-block after exercise.
20						Feels poorly, bilious. Some palpitation and a little short of breath.
21	3xx Squills stopped	84		1½-5		Palpitation occasionally but not so frequently as on admission. No pain.
23		68				No palpitation on exertion, but slight dyspnœa. All irregularities gone, even after exercise.

CASE 25, female, aged 31. Normal rhythm. Mitral stenosis. Digitalis and strophanthus improved the patient and decreased the heart rate.

Dressmaker, admitted October the 25th, 1910, complaining of weakness and shortness of breath.

History. The patient had suffered from her heart for 9 years. In the spring of 1909 she had had influenza, which left her with a cough. She expectorated several clots of blood in July, 1910. She gave no history of rheumatism or chorea but had frequently suffered from sore throat.

State on admission. She was pale but fairly well nourished, and was comfortable when lying down with the shoulders raised. The pulse was quite regular, its rate was about 80 per minute. The apex beat was in the 5th interspace and a thrill preceded its impact. The heart's dulness lay 1 and 4 inches to right and left of the mid-sternal line. At the apex there was a murmur preceding and running up to the first sound and another murmur following it; there was also a murmur following the second sound. The presystolic and diastolic murmurs were only heard at the apex, while the systolic murmur was heard over the whole of the cardiac region and in the axilla.

Treatment and progress. After resting in bed for a week a slight improvement took place and the pulse rate slowed. She was put on tincture

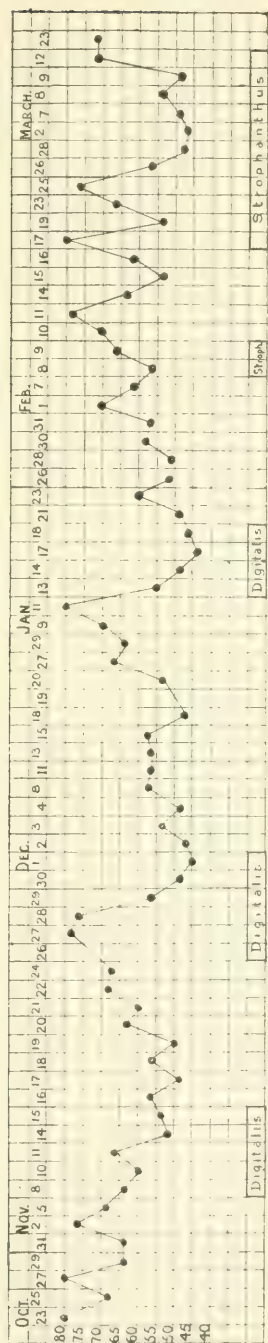


Fig. 37. Chart of CASE 25.

of digitalis, 20 minims thrice daily, on November the 8th. This was continued till the 15th when she had taken $6\frac{1}{2}$ drachms. The effect of the digitalis was to slow the pulse and cause the patient to be conscious of the heart's beat. By the 26th the pulse rate was somewhat increased, and the patient was again put upon the digitalis, 15 minims four times a day. This was continued till December the 2nd when she had taken $5\frac{1}{2}$ drachms. This again slowed the pulse and produced a marked sinus irregularity after exertion. She was conscious of her heart thumping in a distressing manner, and she felt nauseated. The day after the drug was stopped she felt very well and continued to do so for the next three or four days. She was kept quiet after this and given no medicine for a time. She became slightly worse and became more breathless after exertion. In some observations on the 7th, the sinus slowing occurred at intervals after the heart had quieted down after exertion. On January the 13th she had attacks of breathlessness when lying in bed, and was again put upon the digitalis, 15 minims four times a day; this was continued till the 19th when she had taken 6 drachms. She felt better after taking three drachms, breathing more easily, but on the 18th she had nausea, vomiting and headache, and the pulse rate had fallen to 44. For the next ten days there was marked sinus irregularity while at rest and occasionally interpolated extrasystoles were detected after the heart had slowed down after exercise. They disappeared as the heart rate increased.

The patient began to be more breathless and on February the 8th, 1910, she was put upon tincture of strophanthus, 15 minims four times a day. This was stopped after taking $1\frac{1}{2}$ drachms, as she began to menstruate and was not feeling well. The same doses were resumed on the 17th and continued till March the 12th, when she had taken 23 drachms. The heart gradually slowed and she was feeling fairly well on the whole. On March the 8th and the 9th when the heart was slower, occasional extrasystoles were detected after exertion. She was discharged on April the 12th, 1910, still taking 15 minims of strophanthus, three times a day. She reported herself on the 23rd as being on the whole fairly well but still having difficulty in breathing in walking up a hill (see Chart, Fig. 37).

DATE.	DRUG.	PULSE RATE.	SIZE.	URINE.	REMARKS.
Oct.					
23		30	1-4		
25		68			
27		80			
29		64		42	
31		64		44	
Nov.					
2		76		36	
5		68		45	
8	Digit. $\overline{3}$ p.d.	64		40	
10		60		52	
11		66		49	
14		52		36	Conscious of every heart beat.
15	$\overline{5}$ wiss Digit. stopped	54		40	Feels beats only occasionally.

DATE.	DRUG.	PULSE RATE.	SIZE.	URINE.	REMARKS.
Nov.					
16		56		40	
17		48		16	
18		56		32	
19		50	1-4	24	
20		64		26	
21		60		42	
22		68		20	
24		67		31	Slight dyspnœa after exercise.
26	3i p.d. Digit.		1 4	40	
27		78		26	Feels stronger, breathing easier.
28		76			
29		56		31	
30		48		40	
Dec.					
1		40		40	Not feeling quite so well, a little faint, but appetite less good, bumping of the heart after exercise.
2	5vss Digit. stopped	42		28	Not feeling well. Nausea. Occasionally feels heart a little.
3		54		23	Feels quite well.
4		48	1-4	30	Feels well.
8		57		40	Feels heart beating unpleasantly, more breathless, wants to sit up. Yesterday had some pain in left breast.
11		56		48	Breathless after exertion.
13		56		40	Feels quite well, no dyspnœa or giddiness.
15		57		32	
18		46		24	Not feeling so well, palpitation again and trouble in breathing.
19					Dyspnœa came on suddenly last night when lying without her pillows, had to sit up.
20		54		50	Breathing easier.
27		66	3-4	40	Feels very well.
29		64		38	
Jan. 1910,					
3				32	Feels fairly well. Occasional slight headache, consciousness of heartbeat.
5				23½	
8				28	
9		70		32	
11		80	1-4½	26	Been up, feels breathless, still some pain now slight, with feeling of tension about top of sternum.
13	3i p.d. Digit.	55			
14		48		18	
16				20	Felt very well yesterday, breathing easier.
17		44		8	Not quite so well, feels a little sick, vomited this evening. Breathing much easier.
18		46	½-4½	22	Better. Slight nausea after taking medicine but soon disappears. No dyspnœa after exercise.
19	5vi Digit. stopped			16	Headache, nausea, vomiting, otherwise feels well. Breathing easy.
20				6	Better, breathing easy.
21		48		26	
23		60		17	Feeling very well, breathing easy.
25				40	
26		52		18	Feels very well.
28		51		40	Feels well.
30		58		35	
31		57	¾-4½	38	
Feb.					
1		70		20	

DATE.	DRUG.	PULSE RATE.	SIZE.	URINE.	REMARKS.
Feb.					
3				25	Feels well.
7		62		40	
8	Stroph.	56		19	Feels breathless and ill, palpitation, pain in left chest last night.
9	5iiss Stroph. stopped	66		29	
10		70		17	
11		78	1-4	13	Feels very ill, all kinds of complaints.
14		64		9	Feels very well, breathing better. Less dyspnœa.
15		53		17	
16		62		10	
17	Stroph.	80		5	
19		54		14	
23		66		40	
25		76		19	
26		56	$\frac{1}{2}$ -4 $\frac{1}{2}$	37	Appetite poor now, otherwise well.
28		47		13	Feels well, no nausea.
March					
2		46	$\frac{1}{2}$ -4 $\frac{1}{2}$	34	
4				22	Some nausea, otherwise feels well.
7		48		20	Feels very well, no nausea.
8		54		20	
9		48		9	
10				36	
12	5xxiii Stroph.	72			Discharged feeling well.
23	stopped	72	1-4 $\frac{1}{2}$		Called at Out-Patient department, feeling very well.

CASE 26, female, aged 45. Normal rhythm. Mitral stenosis. *Strophanthus* caused diarrhœa on two occasions, but had no appreciable effect on the heart rate.

Admitted March the 3rd, 1910, complaining of shortness of breath, pain over the front and left side of the chest and cough.

History. The patient had had vague rheumatic pains in her joints for one year. She had had cough at times for many years but more during the five months preceding admission. She sometimes brought up half a cupful of sputum, yellow and occasionally streaked with blood. She was losing weight. She was married and had four children and one miscarriage.

State on admission. The patient was a small wasted woman. The pulse was regular; its rate was 84 per minute. The apex beat was in the fifth interspace outside the nipple line. The heart's dulness lay 1 $\frac{1}{2}$ and 4 $\frac{1}{2}$ inches to right and left of the mid-sternal line. At the apex there was a presystolic murmur running up to the first sound. There was a soft murmur following the first sound, the second sound was reduplicated and followed by a short murmur. At the aortic area the second sound was markedly reduplicated. The systolic murmur was best heard over the middle of the sternum. At the base of the left lung there was a patch of dulness over which the breathing was bronchial in character. In the neighbourhood there were numerous râles and rhonchi.

Treatment and progress. On March the 5th the patient was put on tincture of *strophanthus*, 15 minims four times a day, and this was continued till the 9th, when she had taken 5 $\frac{1}{2}$ drachms. On the 7th she was seized with diarr-

hæa and on the 9th there was a good deal of abdominal pain in addition. The diarrhœa persisted for four days and she was given castor oil on the 10th and 11th. She had two motions on the 11th and the diarrhœa ceased. The heart was not affected in any appreciable way. The patient seemed better after this and there was less cough. On March the 19th she was again given 15 minims of the tincture of strophanthus; it was continued till the 22nd, when she had taken $3\frac{3}{4}$ drachms. Diarrhœa set in and there was some abdominal pain. On the 23rd she was given castor oil and in a couple of days the diarrhœa had stopped. Again there was no appreciable change on the heart, though the patient felt better afterwards. She was discharged on April the 4th only slightly improved, the improvement was probably due to the rest and proper feeding.

DATE.	DRUG.	PULSE RATE.	SIZE.	URINE.	REMARKS.
March					
3		88	$1\frac{1}{2}$ - $4\frac{1}{4}$	20	Dyspnœa and cough troublesome.
4		76		40	
5	Tr. Stroph.	84		35	
6	\mathfrak{Zi} p.d.	92		12	
7		68		16	
8		84		18	Diarrhœa, loose offensive stool,
9	\mathfrak{Zvss} Stroph. stopped	84		8	Pain in abdomen.
10		76		18	Abdominal pain.
11		80		18	
12		68		$16\frac{1}{2}$	Better, diarrhœa stopped.
14		68		15	
16		72		16	
18		80		16	Cough better, no pain.
18	Tr. Stroph.	76	.5	22	
20	\mathfrak{Zi} p.d.	80		11	
21		78	1.5	11	Feels well. Some dyspnœa after exercise.
22	\mathfrak{Ziii} & m. 45 Stroph. stopped	72		19	Diarrhœa, liquid offensive stool. Abdominal pain travels down midline before bowels are moved. Slight headache.
23		70		16	Better, little diarrhœa this morning.
24		82		14	Severe headache, still diarrhœa.
25		80		18	Better.
31		80		48	Feels well.
April					
4		60	$2\frac{1}{2}$ - $4\frac{1}{2}$	$44\frac{1}{2}$	Feels well, cough troublesome.

CASE 27, male, aged 16. Normal rhythm. Mitral and aortic disease. Digitalis produced heart-block, extrasystoles and pulsus alternans, it increased the flow of urine, but had no effect on the auricular rate.

Admitted October the 20th, 1910, complaining of shortness of breath, pain in the left chest and swelling of the legs and abdomen.

History. The patient had been well up till five years of age, when he began to be short of breath. From this age until admission he had been five times in hospitals. There was no history of rheumatism or sore throat. For some weeks before admission his breathing had been getting worse and his legs had begun to swell.

State on admission. The patient lay propped up in bed; the breathing was laboured. The face was pale, puffy and rather distressed looking. The radial pulse was large, collapsing and regular. The apex beat was large and diffuse outside the nipple line in the fifth and sixth interspaces. There was a rough systolic murmur at the apex and at the aortic area there was a faint diastolic murmur. Both bases of the lungs behind were dull, and there were numerous fine crepitations with deep breathing. The jugular veins were full and pulsating. The liver extended three inches below the costal margin and pulsated. Both the liver and jugular pulsations were of the ventricular form as a rule, but occasionally there was a small auricular wave in each. There was some fluid in the abdominal cavity, and the legs and thighs were swollen. There was a slight trace of albumen in the urine.

Treatment and progress. The patient was very ill on admission. On the day after admission, he vomited and expectorated some blood-stained sputum. On October the 23rd he was found in a state of collapse, the pulse was small, rapid (140-150) and regular, the extremities were cold, the face pallid, the ears blue. He was very restless, the *alae nasi* were working, the breathing was distressed. After an inhalation of oxygen and a hypodermic injection of digitalin he rallied. Some hours after he had another attack and again rallied in half an hour. On the following day he was put on tincture of digitalis, 20 minims three times a day, and he gradually improved, the urine increasing and the ascites and dropsy disappearing. The digitalis was continued till November the 9th, when he had taken 15 drachms. On November the 7th his pulse became slower and irregular as a result of partial heart-block, the auricular contractions being unaffected. He vomited on November the 7th and 9th and the drug was stopped on the latter date. The patient's general condition was much improved and he felt brighter and better, though the heart's rate and size were not much affected. During this period his temperature was always slightly raised. After a week's cessation of the digitalis it seemed as if the heart was increasing in size, so he was again put on tincture of digitalis, 20 minims three times a day, and this was continued till the 24th when he had had 9 drachms. On the 21st his radial pulse rate fell to 100 and became irregular, owing to partial heart-block; an examination of the jugular tracing showed no change in the auricular rate and rhythm (Fig. 38 and 39). There were also occasional extrasystoles and the pulsus alternans (Fig. 40). Early in the morning of the 25th he vomited and the drug was stopped. From this date he continued to feel very well and comfortable, though there was only a slight improvement in the heart's condition. The liver dulness varied much from time to time without any coincident change in the heart. (See Chart, Fig. 41).

(For an analysis of the heart irregularities and the effect of atropin, see pages 292 and 297).

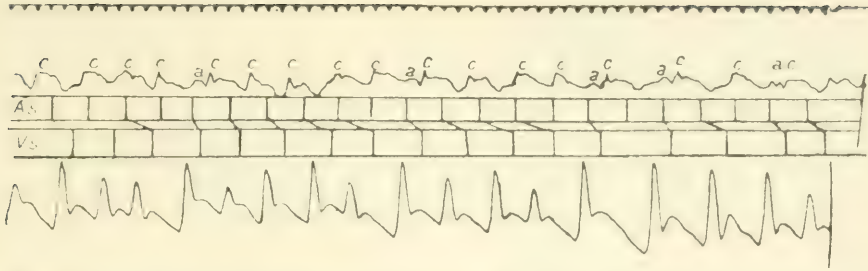


Fig. 38. Shows the irregular pulse produced by digitalis. The tracing from the neck is a mixture of the jugular and carotid pulses, and most of the auricular waves *a* are not distinct. The intercalated diagram explains the relation of auricular to ventricular rhythm, and shows that the irregularity of the radial pulse is due to partial heart-block (see Fig. 52 CASE 27).

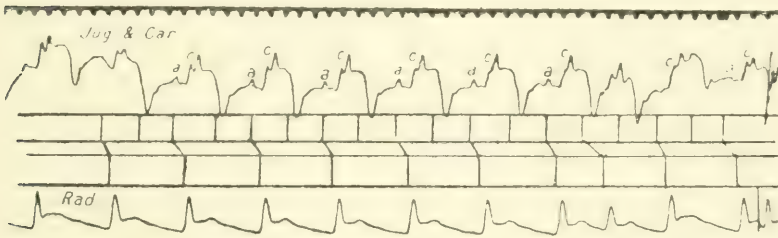


Fig. 39. The tracing from the neck is a mixture of the jugular and carotid pulses, and every second auricular wave is not distinct. The intercalated diagram shows that there is one ventricular contraction to two auricular contractions. (2 : 1 rhythm, except in one instance, see Fig. 52, CASE 27).

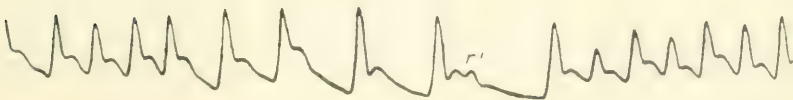


Fig. 40. Tracing of the radial pulse, showing an extrasystole *r'* followed by the *pulsus alternans*. The long pauses before the extrasystole are due to heart-block (CASE 27).

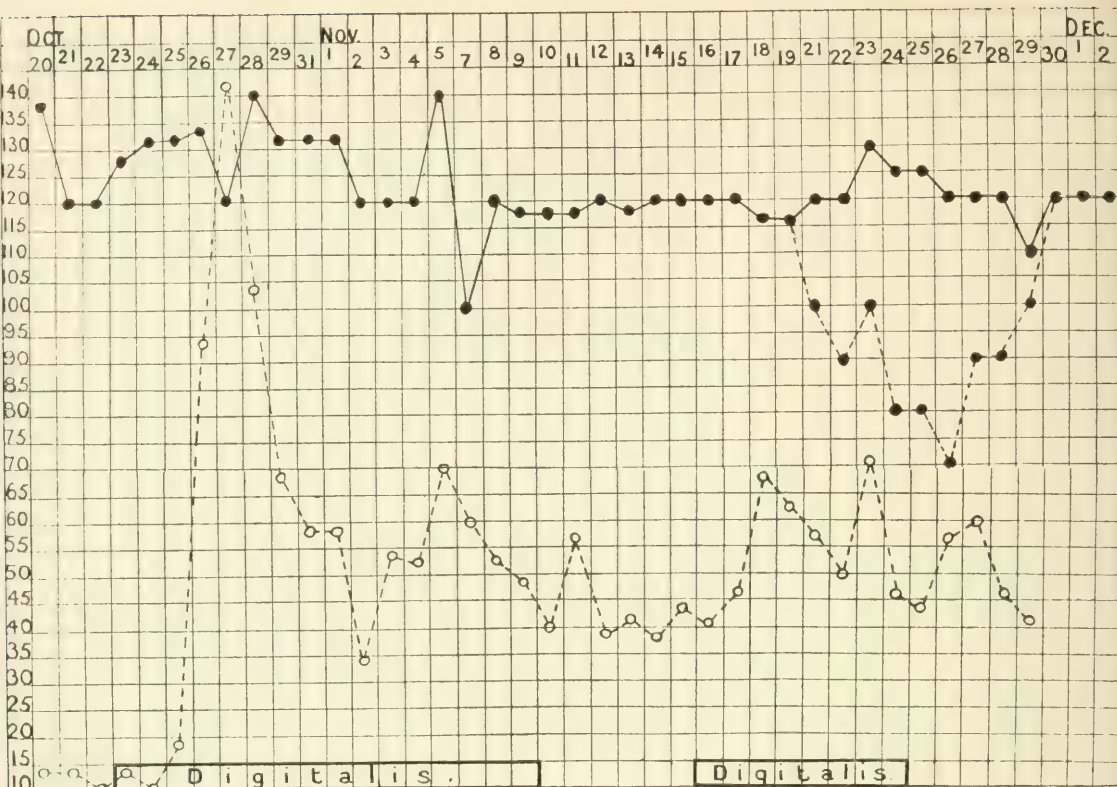


Fig. 41. Chart of CASE 27. The solid line represents the heart rate, but where the interrupted line occurs during a period of partial heart-block, the solid line represents the auricular rate and the interrupted line the ventricular rate. The interrupted line with circles represents the amount of urine.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	SIZE.	URINE.	REMARKS.
Oct. 20		138		2½-5¾	14	
21		120			14	Vomited and expectorated blood streaked phlegm.
22		120			10	Vomited several times. Feels much better to day. Coughing less, breathing easier.
23		128			14	Collapse.
24	Digit. 5i p.d.	132			5	Better. Still restless, has terrifying dreams. Vomiting.
25		132			19	No vomiting, feels easier.
26		134	120	1½-5	94	Very much better, dyspnoea gone, can lie down and move about in bed quite comfortably.
27		120	132		141	Feels very well.
28		140	126		104	
29		132	120		68	
30					56	
31		132	130	1½-4¼	58	
Nov. 1		132	130		34	
2		120	132		54	Feels well, looks pale. Lungs clear.
3		120	120	1½-5	53	Feels well.
4		120	114		70	Feels well.
5		140	130		60	Feels well.
7		100	130		53	Feels well, vomited twice to-day. Pulse irregular (partial block).
8		120	124		49	Feels well, pulse regular, no more vomiting.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	SIZE.	URINE.	REMARKS.
Nov. 9	5xv Digit. stopped	118			57	Vomited twice this morning. Pulse irregular.
10		118	128		40	Feels well, no nausea, pulse regular.
11		118	118		44	Feels well, liver 3 inches below ribs.
12		120	128		34	Feels well.
13		118	116		42	
14		120	130		39	Feels well.
15		120	118	2 4-6 1	44	Feels well.
16	Digit.	120	118		42	Feels well.
17	3i p.d.	120	120		47	Feels well.
18		116	122	2 6	68	Slight headache last night.
19		116	118		63	No headache.
20		A120* V100	112	1 3-6	57	Feels well.
22		A120 V 90	120		50	Feels well, pulse irregular, partial block.
23		A130 V100	120		71	Feels well.
24	3ix Digit. stopped	A125	134		46	Feels well.
25		V 80 A125	134	1 1/2-3 1/2	44	Vomited twice this morning.
26		V 80 A120	134		51	Feels very well.
27		V 70 A120				
28		V 90 A120	108	1 1/2-5	60	Feels well.
29		A110 V100	120		64	Feels well.
30		A120 V120	130		46	Feels well.
Dec. 1		120	126		41	Feels well.
2		120	114			

* A and V. The auricular and ventricular rates respectively, counted from the graphic records (see Chart, Fig. 41.)

CASE 28, male, aged 41. Normal rhythm. Aortic disease. Rheumatic history. Digitalis caused diuresis, and the raised blood pressure; it did not decrease in rate. Sudden death. Post-mortem.

Chimney Sweep, admitted October the 16th, 1910, complaining of shortness of breath and swelling of legs.

History. The patient considered himself quite healthy until three months before admission when he had become short of breath on climbing stairs. This breathlessness gradually increased, and was so great that he could not walk about or lie flat in bed. Nine days before admission he noticed that his legs were swollen. He had micturated three or four times in the night for some years. He had had rheumatic fever three times, in 1891, 1893 and 1901. He was a soldier for thirteen years.

State on admission. The patient lay propped up in bed, looking very ill, the breathing was laboured at a rate of 32 per minute. The face was dusky and the lips cyanosed; there was a slight jaundiced tinge of the conjunctivæ. There was some swelling of the legs, and a good deal of oedema of the back

over the sacrum. The tongue was covered with a thick fur. The radial pulse was large, regular and slightly collapsing. The arterial wall was thick and somewhat tortuous. The jugular veins were very full and pulsated. The heart's impulse was diffuse and the apex beat was in the sixth inter-space and two inches outside the nipple line. The heart's dulness lay $\frac{3}{4}$ and $8\frac{1}{2}$ inches to right and left of the mid-sternal line. At the apex there was a systolic murmur, heard also in the axilla. At the base there was a double murmur, systolic and diastolic in time, and heard loudest in the aortic area. The urine contained a faint trace of albumen (sometimes absent) and no sugar.

Treatment and progress. The patient was maintained at rest and his bowels were kept open by a rhubarb mixture and an occasional dose of calomel. He had no appetite and vomited several times during the first few days after admission. The temperature showed a slight rise. After this there was a little improvement, his breathing was not so distressed but he still had to be propped up in bed and the oedema persisted. On the 18th of October he was put on tincture of digitalis, 20 minims three times a day, and this was continued till the 25th when he vomited and it was at once stopped. He had taken 7 drachms altogether. After he had taken between three and four drachms he felt much better, could breathe more easily and lie flat in bed, while the flow of urine increased, the oedema disappeared and the jugular distension and pulsation were no longer visible. There was a rise in the blood pressure. On the morning of the 26th October, he suddenly died (see Chart, Fig. 42).

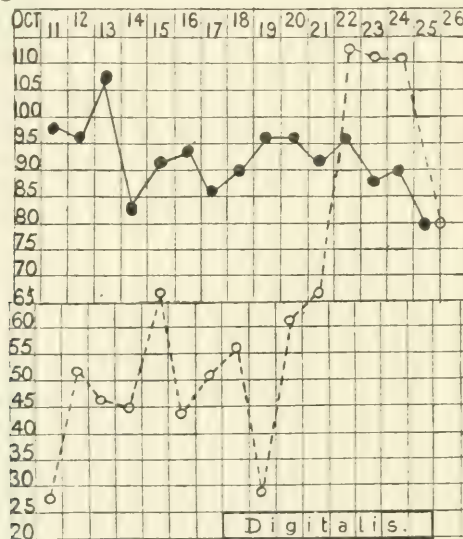


Fig. 42. Chart of CASE 28. The solid line represents the pulse rate and the interrupted line the amount of urine.

The heart was removed. Professor Woodhead's report accompanies these notes.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	URINE.	REMARKS.
Oct.					
11		98	170	28	Orthopnœa and cyanosis.
12		96	180	52	Very breathless, vomited.
13		108		47	
14		84	180	45	
15		92		67	
16		94		44	
17		86	174	51	Attack of bad breathing in the night.
18	Tr. Digit. $\bar{5}$ i p.d.	90	174	56	Distressed breathing in the night.
19		96		29	Feels better.
20		96		61	
21		92		66	Feels much better. Cyanosis gone.
22		96		133	
23		88		112	Dropsy gone.
24		90	198	120	Feels very well, able to lie flat.
25	$\bar{5}$ vii Digit. stopped	80	198	80	Vomited, feels ill.
26					Died suddenly.

Post-mortem notes.

The *heart* weighed 24 oz. Much enlarged; milk spot on front of apex of left ventricle three-quarters of an inch from apex and extending 1 inch upwards; thinner milk spot on right anterior surface of right ventricle. An old adhesion between the auricular appendix and the upper border of right ventricle, midway between extreme margin and interventricular groove, just above the auriculo-ventricular groove. Some slight thickening of front of auricle and appendix; the same in front of left auricular appendix. Some old adhesions between auricle and ventricle, extending over left outer margin of auricle down to *A-V* groove, where the large lateral artery and vein run in the external left ventricular groove. A large colourless clot in the right auricle, ante-mortem in body of auricle but not in appendix. Wall of left ventricle greatly hypertrophied; the greatest thickness seven-eighths inch, three-eighths at apex and a quarter inch at base. Musculi papillares and heart muscle of wall slightly mottled, fatty and somewhat pale. Right ventricular wall also hypertrophied, one-eighth to three-eighths inch thick; some mottling. Both auricles dilated. Pectination of muscles well-marked in right auricle. *Pars membranacea* well marked between the auricles; remains of valve but no opening. The endocardium in left auricle very considerably thickened, much wrinkling. *Striae* under endocardium well marked. Aorta shows well-marked atheroma, but not of very long standing, and with little calcification; slight thickening of margins of cusps of aorta but valves fairly competent. A somewhat enlarged sinus immediately above the valve, especially where the coronary arteries come off. Some thickening of mitral valves in their bases, but the flaps of the cusps, where attached to the *chordae tendineae*, fairly normal; some fatty degeneration at the base of anterior cusp. Tricuspid valve fairly normal, but a little thickening at base with some patches of fatty degeneration. Pulmonary artery somewhat thickened, especially endocardium.

Considerable amount of fat along *A-V* groove and especially in front and to the right of the right *a-v* surface, extending right away down to apex.

Piece of aorta : advanced atheroma, but no great calcification. Some contraction.

Liver : fatty, with slight central venous congestion.

Spleen : some congestion, probably chronic, firm, hard ; somewhat congested, probably slight increase of fibrous tissue.

CASE 29. female, aged 20. Aortic and mitral disease. Normal rhythm. Digitalis had no effect on the heart rate or blood pressure.

Admitted June the 30th, 1910, complaining of pain in left chest and shortness of breath.

History. The patient had had several attacks of rheumatic fever. Her first attack was at 15 years. The last attack was in February 1910. Shortness of breath had always been easily induced from her fifteenth year.

State on admission. The patient was a spare, nervous girl, who lay propped up in bed. The pulse was regular but collapsing ; its rate was 96 beats per minute. The apex beat was large and diffuse in the sixth interspace. The heart's dulness lay $1\frac{3}{4}$ and 6 inches to right and left of sternum. At the apex there was a rough systolic murmur. At the aortic area there were systolic and diastolic murmurs, the latter propagated down the sternum.

Treatment and progress. The patient was kept at rest for a week, after which she was given tincture of aconite for two weeks, but it had no effect upon her. She was put on tincture of digitalis, 15 minims four times daily, on June the 18th, and this was continued till the 24th, when she had taken 5 drachms. On this date she had a headache and vomited. Neither the pulse rate nor the blood pressure was affected. On the 25th she felt very well, in fact better than upon any day since she had been in the hospital. She was kept at rest after this, but as she did not improve, she was put on aconite on July the 4th and this was carefully pushed, but with no effect on the heart, save perhaps to accelerate its rate. On September the 7th she was again put on tincture of digitalis, 15 minims thrice daily, and this was continued for ten days. On the 14th and two following days she had headache and vomiting, and the drug was stopped on the 17th ; from that date she was free from vomiting and also felt much better. Neither the heart rate nor the blood pressure was appreciably affected, but her general condition was slightly improved when she was discharged on September the 22nd (see Chart, Fig. 43).

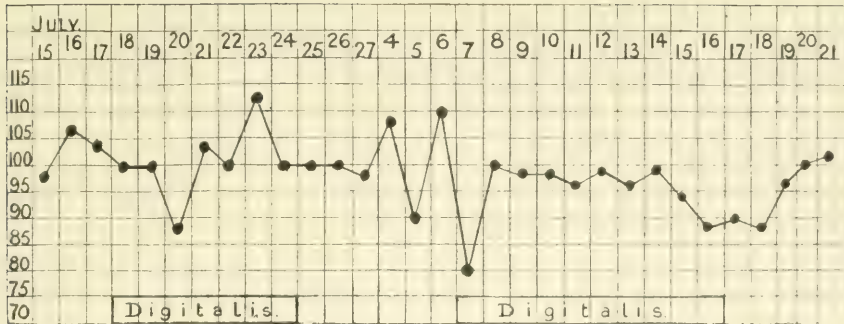


Fig. 43. Chart of CASE 29.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	URINE.	REMARKS.
July.					
15		98	144	10	
16		106		21	
17		104		30	
18	Digit. $\frac{3}{4}$ p.d.	100	154	34	
19		100		19	
20		88		22	
21		104		29	
22		100		24	
23		112		27	
24	$\frac{5}{8}$ Digit. stopped	100		24	Vomited, headache.
25		100	142	18	
26		100			
27		98		16	
Sept.					
4		108	140	34	
5		90		20	
6		110	130	40	
7	Digit.	80		40	
8	$\frac{4}{5}$ m. p.d.	100	134	36	
9		98		40	
10		98		35	
11		96		40	
12		98	120	32	
13		96		22	
14		99		23	Vomited.
15		94		28	Vomited and headache.
16		88	138	24	Vomited and headache.
17	$\frac{3}{4}$ Digit. stopped	90		20	Better.
18		88		20	
19		96		40	
20		100		36	
21		102	144	30	
22		104			

CASE 30, female, aged 61. Normal rhythm. Aortic disease. Frequent ventricular extrasystoles. Emphysema. Digitalis and squills had no perceptible effect upon the heart.

Admitted April the 20th, 1910, complaining of weakness, shortness of breath and attacks of breathlessness and suffocation after exertion. Also a good deal of pain in the left chest at times.

History. The patient enjoyed very good health till two years before admission, when she seemed to age rapidly and became weak and short of breath. The legs had swollen at the end of a day's work, and she had to get up several times in the night to micturate. She was married and had had eight children. Her work had been heavy during the later years.

State on admission. She looked thin and pale, lay quietly and comfortable in bed but was breathless on exertion. The pulse was regular, save for the presence of frequent ventricular extrasystoles. The chest was somewhat emphysematous and the heart's dulness could not be mapped out accurately. The sounds were clear and the aortic second was slightly accentuated. The blood pressure was 142 mm. Hg..

Treatment and progress. As it was manifest that the patient was thoroughly exhausted, she was at first treated simply by rest. She gradually regained a good deal of strength, and many of her more distressing symptoms disappeared before she was discharged on July the 12th. As the extrasystoles persisted, we tried to see if digitalis would affect them, but although it was pushed till she vomited, it had no effect upon their frequency. Bromide of ammonium was also given, 80 grains per day for three weeks, but it had no effect on the extrasystoles. She was put on tincture of squills, 20 minims three times a day, on June the 20th, and this was continued till July the 11th, but it had no effect upon the extrasystoles, unless it caused them to occur more frequently. Towards the end of her stay in the hospital, a faint systolic murmur could be detected in the aortic area.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	URINE.	REMARKS.
April 28		96	142	42	Cough, sense of suffocation at night.
May 2		84		44	Feeling better, scarcely any sense of suffocation.
8		70		61	Better.
9				30	
13		84		53	
18				38	
19	Tr. Digit. ζ i p.d.			56	
23		84		38	Feeling much better in every way. No cough.
24		78		40	
25		72		52	
26		80		43	
27	ζ iv $\frac{1}{4}$ Digit. stopped	72		58	Not feeling well. Occipital and parietal headache. Sleeping poorly. Nausea.
28		74		25	Vomited.
29		82		16	Feels wretched. Been vomiting. Headache.
30		84	134	18	Feeling better but still nauseated.
June. 1		88	138	34	Feeling much better.
2		84		38	
4		80		47	
5		88		42	
15		100	146	38	

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	URINE.	REMARKS.
June 16		100	132	56	
17				58	
20	Squills	100	144	22	
21		86		34	
22		100	154	35	
24		102		29	Feeling better.
30		92	134	29	
July 2		90		28	
4		98		59	
7		96		47	
11	5xxi Squills stopped	84	144	39½	Feels well.

CASE 31, female, aged 46. Normal rhythm. Mitral and aortic disease. Rheumatic history. Digitalis produced vomiting, but had practically no effect upon the heart, and seemed to lower the blood pressure.

Married, admitted December the 1st, 1909, complaining of cough and shortness of breath. Pain and tightness across the chest.

History. The patient was married and had had eight children. She had suffered from rheumatism each winter from the time of her youth, but there was no definite history of an attack of rheumatic fever. Four months previous to admission she began to suffer from shortness of breath and pain across the chest on exertion; her legs had swollen. She suffered also from attacks of palpitation even when lying quiet.

State on admission. The patient was a big, fat and florid woman. She preferred to be in bed and propped up. The pulse was regular. The apex of the heart was $1\frac{1}{2}$ inches outside the nipple line in the sixth interspace. At the apex a systolic murmur was heard. At the base a systolic murmur, conducted along the carotid, and a soft diastolic murmur, conducted down the sternum, were present.

Treatment and progress. The patient was kept in bed for most of the three weeks after admission; she improved slightly and the swelling of the legs disappeared. On December the 12th she was put on tincture of digitalis, 15 minims four times a day, and this was continued till January the 1st, 1910, when she had taken $8\frac{1}{4}$ drachms. She continued to improve, though the pulse and blood pressure were unaffected. She had headache and was nauseated on January the 1st. A pulse rate of 54 and one of 100 was noted on this date and the drug was stopped. The headache passed off in a couple of days and she felt much better, and was discharged on January the 14th (see Chart, Fig. 44).

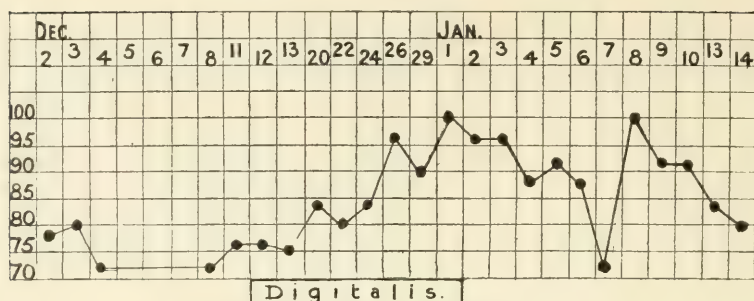


Fig. 44. Chart of CASE 31.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	SIZE.	URINE.	REMARKS.
Dec.						
2		78				
3		80	140		9½	
4		72	126		23	
5					29	
6					30	
7					36	
8		72	140		64	Feels better.
11		76	136	¾-6	35	Feels very well, no pain now.
12	Tinct. Digit.	76			36	
13	5i p.d.	75		1-5½	30	Feels very well. Giddy after walking up flight of stairs.
						Feels quite well.
20		84	120			
22		80	126		16	
24		84	124		60	
25		96	114	1-5½	55	Feels very well. No pain.
26		96	114			No cough.
29		90	114	1-5½	55	Feels very well, sleeps well.
Jan.						
1	3xviii ¾ Digit. 54-100 stopped				12	Not feeling quite so well. Headache, slight nausea.
2		96			21	
3		96	112		57	Feels quite well again.
4		88			58	No headache.
5		92			54	
6		88			21	
7		72			51	
8		100			32	
9		92			40	Feeling well.
10		92			40	
13		84	110		36	
14		80	118		30	Feels very well in every way.

CASE 32, male, aged 18. Normal rhythm. Mitral and aortic disease. digitalis was without effect upon the heart. Died. P.M. report.

Admitted March the 8th, 1910, complaining of weakness, breathlessness on exertion, and pain in breathing.

History. The patient had had several attacks of rheumatic fever five years before admission and had never been very strong. He had been working with a blacksmith and swinging a 7 lb. hammer up till five weeks before admission. He had had to stop work as he was very short of breath, attacks of dyspnoea coming on suddenly and lasting from 10-20 minutes.

State on admission. The patient was a frail and delicate looking boy, but bright and intelligent. He lay propped up in bed, the face slightly flushed. The pulse was regular; its rate was 88 per minute. The apex beat was in the sixth interspace, one inch outside the nipple line. The heart's dulness lay 1 and 4 inches to right and left of the mid-sternal line. At the aortic area there were well marked systolic and diastolic murmurs; they were heard also all over the heart. At the mitral area there was a systolic murmur of a different character, and it was propagated into the axilla. There was marked capillary pulsation after rubbing the skin of the forehead. The liver was large, extending three inches beyond the ribs and pulsating. A tracing of the pulsation showed it to be of the auricular form. There was no swelling of the legs. The urine was free from albumen.

Treatment and progress. The patient was at first treated by rest alone and for a while he seemed to improve, but as time went on his temperature began to rise at irregular intervals. In the middle of April his temperature rose steadily for a week to 103 Fahr., during which time he was very ill. It suddenly fell, and his condition improved. Various remedies were tried with little or no beneficial effect and he died on June the 6th, with symptoms of extreme heart failure. Digitalis was given on two occasions, once in April when it had to be stopped as the patient was suffering much from obscure pains in his shoulder joint. It was again tried in May and, although pushed until he was sick, it had no effect upon the pulse rate. During this time the temperature rose a little above the normal. It will be observed that the blood pressure rose as his heart was failing (see Chart, Fig. 45).

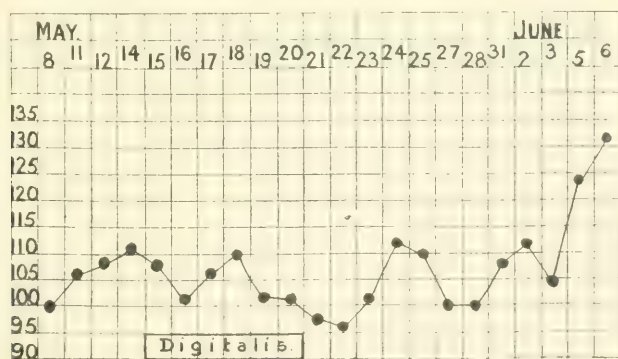


Fig. 45. Chart of CASE 32.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	REMARKS.
May 8		100	104	
11		106		Feels very ill, distressed breathing.
12		108		Same.
14		112		Feels better, hallucinations. Crepitations at both bases.
15	Digit. $\frac{3}{4}$ p.d.	108	128	Feels ill.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	REMARKS.
May 16		102		Feels ill, breathing distressed.
17		106		
18		110		
19		102		Feels much better, nausea.
20	5v Digit. stopped	102		Vomited. Liver one inch below ribs.
21		98		Feels better but very short of breath.
22		96		Base of right lung dull and crepitations.
23		102		Very ill, restless and sleepless.
24		112	126	Very ill, pallid. Liver $1\frac{1}{2}$ inch below ribs.
25		110		Vomited, never slept. Very ill.
27		100		Slightly better.
28		100		Much better. Liver 3 inches below ribs.
31		108	124	
June 2		112	136	Very ill, dulness at both bases.
3		104	130	
5		124	134	
6		132		Died.

Professor Woodhead's report of the post-mortem examination.

Weight of heart with adherent pericardium, 1 lb. $10\frac{1}{2}$ oz., without pericardium, 1 lb. 2 oz.

Length of cavity of left ventricle 8.5 cm.; thickness of wall 1.5 cm. down to 0.5 cm. at apex. Some thickening of apices of musculi papillares. Adhesion of mitral valve at free margins. Small vegetations at lower portion of somewhat funnel-shaped orifice; cusps contracted and thickened. *Chordae tendineae* opaque and perhaps slightly contracted. Aortic orifice somewhat narrowed, cusps thickened, contracted, slightly granular, small vegetations along thickened margins; no atheroma of aorta. Coronary arteries slightly thickened and narrowed.

Right ventricle: length of cavity 6.0 cm., thickness of wall 0.4-0.15 cm., somewhat dilated, muscles slightly mottled. Pulmonary cusps normal, tricuspid valve normal, perhaps some thickening and opacity of musculi papillares. Right auricle dilated, coronary vein very wide, some thickening of endocardium, especially at base of tricuspid valve.

Old adhesions on the outer side of upper half of the left ventricle coming forward somewhat to the front. Adhesions over aorta and pulmonary artery. Left ventricle greatly distended and filled with clot. Right ventricle contains a smaller clot. Clot in both pulmonary veins. Large amount of mucus in the bronchus on both sides; a gelatinous mucus almost like fibrin.

CASE 33, female, aged 46. Normal rhythm. Aortic and mitral disease. Digitalis and squills had no apparent effect on the heart.

Admitted January the 26th, 1910, complaining of shortness of breath and cough.

History. The patient had had a winter cough for many years. Four years ago her legs had swollen, but there had been no swelling during the two years prior to admission. Palpitation had been present during exertion and paroxysms of coughing.

State on admission. The face was pale and rather pinched, the lips were dark. She was well nourished. The chest was barrel-shaped and hyper-resonant. The apex beat was in sixth interspace and outside the nipple line. The heart's dulness lay $1\frac{1}{2}$ and 5 inches to the right and left of the mid-sternal line. The pulse was anacrotic and regular, save for the occurrence of an occasional extrasystole. At the apex the first sound was loud and slapping and preceded by a short murmur; the second sound was followed by a faint diastolic murmur. At the aortic area there was a soft blowing systolic murmur, heard also in the carotids, and a diastolic murmur.

Treatment and progress. The patient was kept at rest in bed for the first five days after admission. On February the 2nd, she was put on tincture of digitalis, 15 minims four times a day, and this was continued till the 6th when she had taken $4\frac{1}{2}$ drachms. On that date she felt sick, vomited and had a severe headache. No change in the heart's action was detected. After the vomiting passed off she felt much better and could undertake exertion with much less distress in breathing. This breathlessness after exercise gradually returned, and on February the 16th she was put on tincture of squills, 15 minims four times a day, and this was continued for ten days; it was stopped after she had taken 11 drachms, because she was having severe headache. She was discharged on the 27th, on the whole a little better, in so far as she could undertake exercise with less discomfort than when she came into the hospital. The squills did not seem to modify the heart's action.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	SIZE.	URINE.	REMARKS.
Jan. 26		90		$1\frac{1}{2}$ - $5\frac{1}{2}$		Short of breath, cough troublesome.
31		82	116		36	Better, cough less.
Feb. 1		90			30	Feels heart beating unpleasantly.
2	Tr. Digit.	84			40	Not feeling heart to-day.
3	3i p.d.	78	122	$\frac{3}{4}$ - $4\frac{1}{2}$	25	Not feeling heart, less dyspnœa after exercise.
4					44	Feels very well.
5					25	
6	3ivss Digit. stopped	80		$\frac{1}{2}$ - $4\frac{1}{2}$	21	Has vomited three times. Severe frontal headache.
7		82	114		34	Headache gone, no nausea (slight this morning), can lie in any position, no discomfort.
8		87			24	Feels well, no cough, markedly less dyspnœa after exercise.
9		92	108		57	Sleeps well. No dyspnœa after exercise.
10		90			52	
11		82			50	Feels very well.
12		80			30	
14		80			51	Complains of tightness in chest, slight cough.
15					43	
16	Tr. Scillao	88	107	$1\frac{1}{2}$ - $4\frac{1}{2}$	58	Cough less, more breathless after exercise
17	3i p.d.	86	120		36	Better, pain and tightness gone. Some dyspnœa after exercise.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	SIZE.	URINE.	REMARKS.
Feb.						
18		72			44	Feels well.
19		88			38	Fairly well.
21		82			49	Feels well.
23		78	135	1.5	40	Sono headache, some dyspnœa after exercise.
25		92			50	Headache.
26	5xi Scill. stopped	88			48	Headache. Dyspnœa after exercise.

CASE 34, female, aged 54. Normal rhythm. Mitral and aortic disease. Extrasystoles. Digitalis caused vomiting. Slight improvement in the general condition, but no appreciable effect on the heart.

Admitted March the 16th, 1910, complaining of great shortness of breath, a suffocating feeling, at times over the throat and chest, and occasional attacks of dizziness and partial loss of consciousness.

History. The patient had been weakly for 30 years, and became worse 17 years before admission when she began to have attacks of semi-unconsciousness. When these came on she felt as if everything was going round, and she would have fallen if she had not held on to a support. She could hear what was going on but was unable to speak. She could usually tell when the attacks were coming and had time to sit down. The attacks usually lasted about two minutes, and they used to come on about once in every six or ten days, but of late years they had been less frequent. Any form of exertion produced shortness of breath and palpitation very readily. She was married at the age of 15, and had had eleven children. There was no history of rheumatism.

State on admission. She looked old and careworn, but could lie in any position without discomfort. The lungs were emphysematous. The pulse was regular except for the occasional occurrence of an auricular extrasystole. The blood pressure was 125 mm. Hg.. The heart's dulness lay 0 and 5 inches to right and left of the mid-sternal line. At the apex there was a long presystolic murmur running up to and terminating in the first sound. The second sound was followed by a short soft murmur. At the aortic area a short systolic murmur and also a diastolic murmur were heard. The Sp. Gr. of the urine was 1020; there was no albumen.

Treatment and progress. The patient was kept at rest in bed, and during this period she felt quite comfortable, but was very short of breath on exertion (going up a flight of stairs). On March the 30th she was put on tincture of digitalis, 15 minims four times a day, and this was continued till April the 4th, when she had taken altogether 4½ drachms. She vomited after the last two doses. While taking the digitalis she showed some improvement, being able to undertake further effort without distress; the drug was stopped because of the vomiting. There was no perceptible effect upon the heart. After the vomiting ceased she felt better on the whole and when discharged from the hospital on April the 17th her general condition

had improved: this was evidenced by her response to effort. Auricular extrasystoles occurred occasionally during the time she was taking the digitalis.

DATE.	DRUG.	PULSE	BLOOD		URINE.	REMARKS.	
		RATE.	REST.	PRES.			SIZE.
March							
18		78	22	125	-5	48	Feels quite comfortable.
21		82	24	110	$\frac{3}{4}$ -5	66	Feels well, dyspnœa only after exercise.
22		90	24	98		40	Feels quite well, sleeps poorly.
23		80	22			56	
24		86	20	96	$\frac{1}{2}$ -5	76	Feels quite well, no pain.
27		72				58	
30	Tr. Digit. 5i p.d.	98	24	100	$\frac{1}{2}$ -4 $\frac{1}{2}$	82	Some oppression in chest past two days, otherwise well. Sleeping better.
31		78	20	110		46	Very slight pain in chest.
April							
1		80				46	
2		74	20	108		40	Not feeling quite so well, sick faint. Less appetite.
3		76				20	
4	5ivss Digit. stopped	80	16	104	$\frac{1}{2}$ -4	25	Vomited last night and to-day feels sick and giddy. Slept better.
5		84				30	Feels better.
6		76	18	106		32	Severe headache, otherwise feels fairly well.
7		72				20	Feels quite well.
11		76	22			60	Feels quite well. Only slightly short of breath on exercise.
14		80		104		64	Feels very well, only slightly short of breath after walking upstairs.

CASE 35. male, aged 39. Normal rhythm. Mitral and aortic disease. Digitalis had no apparent effect on the heart.

Electrician, admitted October the 11th, 1910, complaining of attacks of palpitation and pain in left shoulder and chest.

History. The patient had had scarlet fever and measles in childhood. Nine years ago he had an attack of rheumatic fever. He suffered for many years from influenza, having had an attack each winter. Three years ago and after an attack of influenza, he became short of breath after exertion, and this continued more or less until admission. Two years before this he began to have pain as well as shortness of breath after exertion, the pain being felt over the left chest below the nipple. Latterly the pain has extended from this region up to the left shoulder and occasionally it has extended down the inner side of the arm to the ulnar side of the forearm and to the fingers. The heart thumped and seemed to stop and cause a choking sensation at times.

State on admission. The patient lay flat in bed; he was pale but fairly well nourished. The pulse was small and regular; its rate was 76 per minute. The heart's dulness was increased and lay 5 $\frac{1}{2}$ inches to the left

of the mid-sternal line. At the apex there was a blowing systolic murmur which was transmitted to the axilla. At the aortic area, there was a faint systolic murmur, transmitted into the carotid.

Treatment and progress. The patient was kept at rest, mostly in bed, and he gradually regained strength, sometimes feeling very well, at other times suffering from pain in the left chest. On October the 18th he was given tincture of digitalis, 15 minims three times a day, and on October the 25th this was increased to four daily doses and continued till the 26th, when he had taken altogether 7 drachms. He was sick on the 25th and vomited on the 26th, but there was no appreciable effect on the heart. The sickness disappeared and the patient continued much as before the drug was taken, some days feeling well, on other days not so well, until his discharge on November the 5th.

DATE.	DRUG.	PULSE RATE.	BLOOD PRESSURE.	URINE.	REMARKS.
Oct.					
11		76	110		
12				52	Pain below left clavicle in night.
14		72		64	Still pain below clavicle.
15		72		84	Feels well, no symptoms.
16				73	
17		74	110		Feels well.
18	Digit.	72		77	
19		72		72	Slight headache.
20		66		73	Slight headache.
21		70		76	Nose bleeding about five minutes.
22		75		63	Slight pain in precordium.
24		78		60	Slight pain still.
25		70		50	Feels sick, no vomiting, frontal headache.
26	3vii Digit. stopped	72	114	60	Feels worse, vomited this morning, frontal headache.
27		74	100	41	Slight headache, no vomiting, nausea.
28		74	118	44	Slight frontal headache, appetite returned
29		70	118	60	Same.
31		72	114	58	No headache, feels well.
Nov.					
1		74	112	66	Suffocating feeling during night.
2		78	110	60	Pain in left breast and down arm for 15 hours.
3		74	108	65	Feels well, no pain.

CASE 36, male, aged 13. Normal rhythm. Aortic and mitral disease. Rheumatic history. Digitalis given over a long period had no effect upon the heart, except for causing extrasystoles and exaggerating the sinus irregularity.

Admitted April the 26th, 1910, complaining of shortness of breath on exertion.

History. The patient had had slight attacks of "rheumatism" but was never laid up till March last, when he was in bed for a week with pain in

his joints. He had been short of breath and weakly from this time until admission.

State on admission. Small, pale but healthy looking boy. He was quite comfortable while lying in bed. The pulse was regular: its rate was 94 per minute. The heart's impulse was diffuse in the third, fourth and fifth interspaces. The heart's dulness lay $1\frac{1}{2}$ and $4\frac{1}{2}$ inches to right and left of mid-sternal line. At the apex a rough systolic murmur replacing the first sound, and a long murmur following the second sound were heard. The temperature was 99 degrees Fahr..

Treatment and progress. The patient felt no discomfort when at rest, but in view of his recent attack of rheumatism, it was deemed advisable to keep him quietly in bed. On June the 3rd, he was given 10 minims of tincture of digitalis three times a day. This was continued till the June the 28th, when he had taken 7 drachms of the tincture. There was no apparent effect till he had taken about 6 drachms, when he felt some nausea. On June the 6th he began to show ventricular extrasystoles (Fig. 46), when the heart

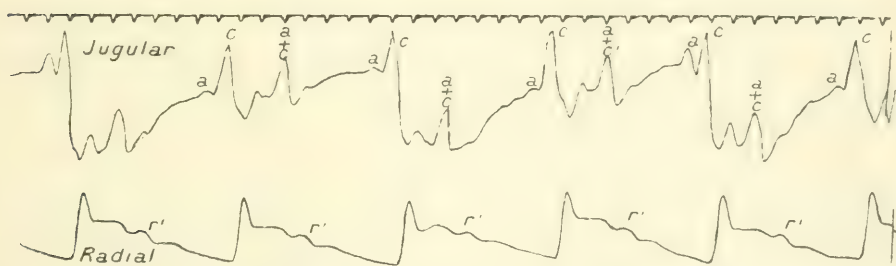


Fig. 46. Tracings from CASE 36. Every alternate beat (r') is due to a ventricular extrasystole.

became quiet after exertion. These could be induced up till the 16th after which date they ceased to appear. On June the 19th the quantity of digitalis was doubled and continued till the 29th, the only symptom shown being slight nausea and giddiness. Before he began the digitalis he showed sinus irregularity when the heart was slowing after exercise, and this continued and became exaggerated during the whole time he was under digitalis. The rate of the heart fluctuated, but it was never much affected by the digitalis. There were frequent slight rises in the temperature during the short time he was under observation.

DATE.	DRUG.	PULSE RATE.	SIZE.	URINE.	REMARKS.
April. 28		94	1½-4½	43	
May 8		90	2-4	50	
10		80		42	
12		81		42	
16		84	1½-3½	54	
24		78	1-3½	51	
27		80		64	
30		84		51	
June. 2		76	½-3½	58	
3	Digit. ʒss p.d.	84	½-3½	65	
4				68	
5		72		58	
6		72		59	
8		72	1½-4		
10		78	1-3½		
12		69			
14		72			
16		81			
17		66			
19	ʒi p.d.	72			
23		66	1½-4½		Feels quite well except for slight nausea.
24		88			Some nausea.
27	ʒxv Digit.	66	1½-4½		
July 3	stopped	72			

CASE 37, male, age 47. *Paroxysmal tachycardia, the tachycardia becoming continuous. Digitalis produced auricular fibrillation and eventually restored the normal rhythm.*

Army officer, admitted May the 3rd, 1910, complaining of great prostration and consciousness of rapid and fluttering action of the heart which was very distressing at times.

History. The patient had been quite well and healthy until 1902. During the South African war he became conscious of occasional attacks of fluttering of the heart. These attacks did not cause much distress till 1905, when they became very frequent and ultimately continued for a few months. After a long rest, the heart became slow and regular in its action for a few years, but during the three or four months preceding admission the attacks had recurred with great frequency and severity, and during the last few weeks the heart had rarely ceased its rapid action and he had become so weak that he had been unable to walk or exert himself. There was no rheumatic or specific history.

State on admission. The patient lay in bed with his shoulders raised. His face was slightly livid and had an anxious expression. He was well nourished and otherwise healthy looking. His pulse was small, soft and regular except for occasional pauses; its rate was 140. The blood pressure was 100 mm. Hg.. The heart's dulness lay 0 and 4½ inches to right and left of the mid-sternal line. The sounds of the heart were like the tic-tac of the foetal

heart, and were free from murmurs. The patient was afraid to exert himself, fearing the heart would go off with a rapidity and violence such as frightened him.

Treatment and progress. The patient at first felt greatly exhausted, the heart persistently beating at a rate between 130 and 150 per minute, with occasional short periods of irregularity at a lower speed. For the first five or six weeks he had attacks during which the heart's rate became enormously increased. These were sometimes provoked by a very slight exertion, such as by standing up for a few moments or by having the bowels moved. A few of these attacks were observed, and the pulse rate graphically recorded, and a speed of between 290 and 300 beats per minute was attained, the highest rate of the human heart I have ever seen graphically recorded. It was utterly impossible to count the heart's rate either from the pulse or by auscultation of the heart. These attacks lasted for half an hour to an hour, and during this time the patient was in great distress. They grew less frequent, and finally disappeared after various remedies had been tried. The pulse rate still continued to be rapid, though it became irregular more frequently. The attacks of extreme rapidity occurred chiefly during the night when he was awakened by disagreeable dreams.

On June the 22nd he was put on ammonium bromide, 20 grains three times daily, and this was continued till July the 22nd. Shortly after beginning the

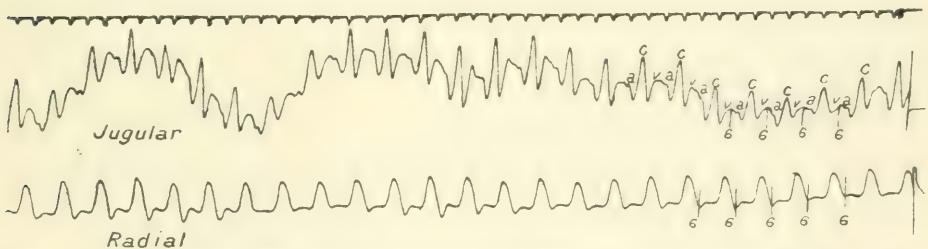


Fig. 47. Tracing of radial and jugular pulse during a period of continuous tachycardia. Rate, 140 beats per minute. The downstroke 6 indicates the time of the opening of the tricuspid valves. Following 6 in the jugular, in place of the fall that normally occurs, there is a small wave *a*, which is in all likelihood due to the auricle. (See electrocardiogram, Fig. 56, CASE 37).

medicine, his nights were more composed and the violent and rapid attacks gradually diminished, till after a couple of weeks they ceased entirely. On July the 22nd he was put on tincture of digitalis, 20 minims three times daily. At this time, his pulse rate was always between 140 and 150 beats per minute (Fig. 47 and 56), with occasional pauses. No effect was produced till the 27th, when 5 drachms of the tincture had been taken and he suffered from nausea. The pulse fell to 55 beats per minute and became continuously irregular (Fig. 48) with occasional paroxysms of rapid rate (140 per minute) lasting for a few seconds. The irregularity was characteristic

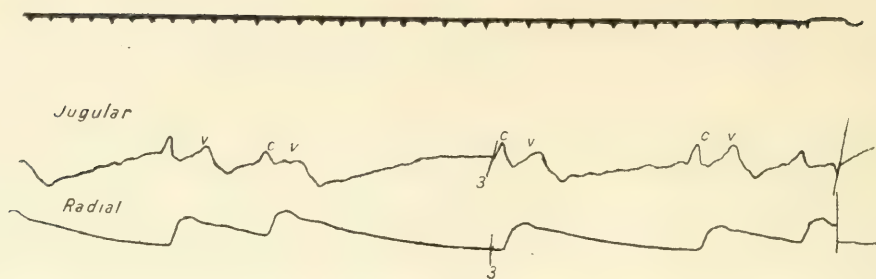


Fig. 48. Shows the irregular pulse due to auricular fibrillation. (CASE 37 on July the 27th, 1910.)

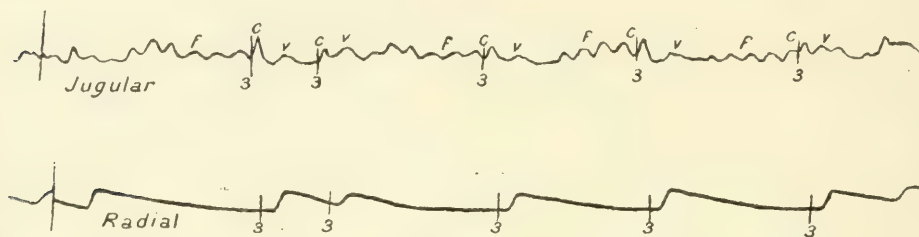


Fig. 49. Slow irregular pulse due to auricular fibrillation, showing the coarse auricular fibrillary waves *f* (compare with the fine waves in Fig. 21 (CASE 11)). (CASE 37 on July the 28th, 1910.)

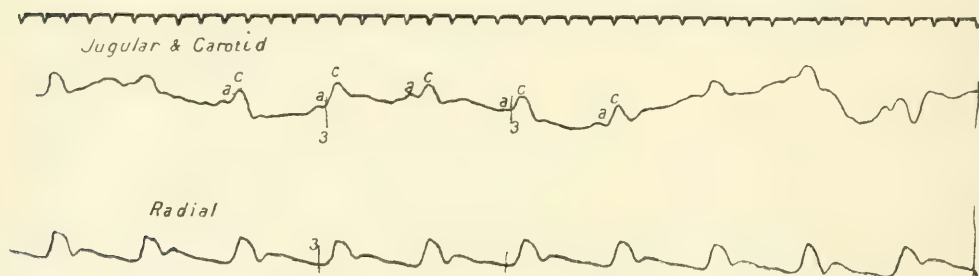


Fig. 50. Shows the normal rhythm occurring at intervals, during auricular fibrillation.

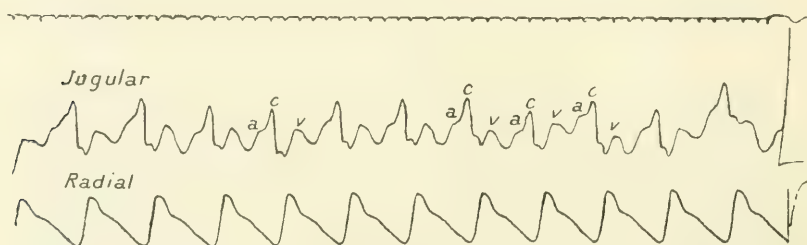


Fig. 51. Shows the normal rhythm when it becomes permanently restored.

of auricular fibrillation and the jugular tracing occasionally showed the fibrillary waves, when the rate was slow and irregular (Fig. 49). On the 28th, periods of regular rhythm at about 70 beats per minute varied with periods of fibrillation at about 50. The regular periods evidently belonged to the normal rhythm and an auricular wave *a* could be detected in the tracing in the neck before the carotid (Fig. 50). The digitalis was stopped on the 28th as the patient felt sick, but was resumed on the 30th and continued in half doses ($\frac{1}{2}$ drachm per day) till August the 7th. From August the 2nd to the 10th the heart beat slowly and irregularly at a rate of from 40-50 beats per minute, and the jugular tracings showed occasionally marked fibrillation waves (Fig. 49). From August the 17th to the 24th the heart's rhythm was very inconstant, showing periods of the normal rhythm, tachycardia and auricular fibrillation. After the 24th the periods of tachycardia became more frequent. On September the 4th the digitalis was resumed at first in 5 minims doses three times daily, on September the 17th it was increased to 10 minims, three times daily; he was kept on this quantity till October the 7th, when he was discharged. On September the 7th, three days after starting the digitalis, the attacks of tachycardia did not last so long, and from this date they gradually decreased till the 29th when the heart became quite steady and the rhythm normal (Fig. 50 and 51). In the tracings we could detect occasional auricular extrasystoles. After his discharge we kept in touch with the patient, who continued to take his digitalis ($\frac{1}{2}$ drachm per day). He gradually regained his strength and the attacks of tachycardia only recurred at rare intervals and for only a few minutes.

CASE 38, male, aged 74. Tachycardia of obscure form. Digitalis produced auricular fibrillation, and finally stopped the tachycardia.

Complaining of weakness and shortness of breath on the slightest exertion, and consciousness of rapid action of the heart.

History. He had been a healthy man up to the end of January 1910, when on waking one morning he felt ill in an indefinite way. He consulted Dr. Ford Anderson, who found his pulse to be beating very rapidly. He kept very quiet for a few days, but getting no better stayed in bed. In spite of treatment and rest his condition remained unaltered.

Condition on May the 10th. He was lying in bed quietly, his breathing easy, though as slight an effort as talking hurried his respirations, but he got up for three or four hours in the evening. The lips and nose were cyanosed. The pulse was rapid, 150 beats per minute, soft and regular, except for an occasional pause. The apex was not palpable and the dulness extended to the nipple line. The sounds were weak but clear. There were distinct

pulsations of the jugular and a tracing showed them to be ventricular in form, though after an occasional pause there was an auricular wave preceding the time of the carotid.

Treatment and progress. On May the 16th he was put on tincture of digitalis, 20 minims three times a day, and this was continued till the 26th, when he had taken 8 drachms; on this date he suffered from nausea. The pulse rate had continued at 150 per minute till the 23rd, when it fell to between 80 and 90 per minute, the rhythm being irregular and of the kind characteristic of auricular fibrillation. On the 26th the rapid rate had again returned (150 per minute), but it was occasionally interrupted by pauses when there would be two or three beats at a slower rate, and an auricular wave was then perceptible in the jugular tracing. On the 25th the pulse was at 150 beats per minute. On the 27th the pulse was regular at 78 per minute, and the jugular tracing showed a well marked auricular wave. The rate on this day was interrupted by a break back into a long paroxysm, lasting two minutes, the rate being 150 per minute. On this day digitalis was resumed, in 10 minim doses three times a day, but was stopped on the 30th as nausea reappeared. The pulse remained at the rapid rate of 150 per minute. Aconite was then tried, but, though various preparations of the tincture were used, they were without effect. In the early part of July the patient was steadily getting worse, the breathing was difficult and attacks of dyspnœa came on from no apparent cause. On July the 8th a second course of digitalis was commenced, one of Nativelle's granules being given three times a day. At this time the pulse rate was 150 per minute and showed marked alternation. On the evening of July the 19th he complained of nausea and the digitalin was stopped after he had taken 33 granules. On the following day the pulse rate had fallen to 76 beats per minute, at times regular and at other periods irregular, as a result of occasional appearance of beats similar to those in the paroxysm. On July the 22nd he complained of feeling uncomfortable and ill; he was very breathless. He was queer in his head, his memory was bad, he was restless, talking a good deal and incoherently. On July the 24th the pulse was perfectly regular at 72 per minute; there was a well marked auricular wave in the jugular pulse at the normal instant. He was still feeling ill and the mental balance had not been quite regained. He knew that his mind was wandering; his memory was bad and his whole mental condition confused.

On July the 27th he expressed himself as feeling very well, better than he had been for a long while; the breathlessness had entirely disappeared and his mind was quite clear. The heart's rate was 72 per minute and the rhythm normal, with the exception of an occasional extrasystole. From this time onward he steadily improved; he went to the seaside where he was quite able to walk for three miles, mostly uphill, with no distress.

CASE 39, male, aged 76. Complete heart-block. Digitalis caused diuresis and disappearance of dropsy with no effect on the ventricular rate. Aphasic attack.

Admitted September the 2nd, 1910, complaining of shortness of breath and swelling of the legs.

History. The patient had had a weak heart for some years. For the three years prior to admission he had had occasional attacks of loss of consciousness. His pulse rate until June, 1910, was usually between 60 and 70 beats per minute, but during his attacks of loss of consciousness it fell as low as 14 per minute. In June he had a series of attacks, losing consciousness forty times in one day. After these attacks had subsided, his pulse rate remained slow, between 25 and 30 beats per minute, and he had no attacks from June till the date of examination. He had however suffered much from breathlessness and swelling of the legs.

State on admission. The patient was a pale thin man, walking about in a slow deliberate manner. When in bed he preferred to lie with his shoulders raised, but he could lie flat. He was not short of breath unless he exerted himself. The pulse was regular at 26 beats per minute. A tracing of the jugular pulse showed three auricular waves to one carotid. The heart was enlarged, the apex beat lay two inches outside the nipple line, and there was a rough systolic murmur, loudest at the apex. The legs were greatly swollen as high as the thighs. The urine was free from albumen.

Treatment and progress. He was treated by rest for a few days, but, showing no improvement, he was put on digitalin granules, one three times a day. He took granules for 5 days, when he became nauseated and felt ill and miserable. He passed large quantities of urine and the dropsy entirely disappeared. He stopped the digitalin and the following two days he was able to go about with greater freedom and felt extremely well, and could do more than he had done for many months. Notwithstanding this the pulse rate remained unaffected at about 30 beats per minute. On the third day after stopping the digitalin he was seized with a peculiar aphasic condition, in which he could neither speak coherently nor write intelligibly, though he seemed perfectly conscious. This passed off in a few hours and left no trace in his speech. After a few days the digitalin was resumed, one granule per day was given. When last heard of he was fairly well and the dropsy was being held in check.

CASE 40, male, aged 37. Normal rhythm. Emphysema. Digitalis had no effect upon the heart.

Admitted November the 29th, 1909, complaining of shortness of breath and cough.

History. The patient had suffered for years from shortness of breath and cough, but had been getting much worse before admission.

State on admission. The patient lay propped up in bed, the face slightly cyanosed. The breathing was laboured. The lungs were hyper-resonant; the chest was characteristically emphysematous. There were numerous moist râles and rhonchi over all parts of the lungs. The cough was very troublesome at times and he brought up a large quantity of white frothy sputum. The heart's dulness could not be made out satisfactorily. There was a rough systolic murmur at the mitral area. The pulse was regular, its rate was 84 beats per minute.

Treatment and progress. For six days the patient was given no drug, but was allowed to rest. On December the 5th he was put on tincture of digitalis, 15 minims four times daily. This was continued till the 11th when he had taken 6 drachms. The digitalis showed no effect on the heart's rate but on the 11th there was a good deal of vomiting and headache. There was little or no improvement in the patient's condition and no treatment gave him much relief. Sometimes when inhaling oxygen he felt better, but the improvement was only transient and he was discharged on January the 13th, 1910, only very slightly improved.

DATE.	DRUG.	PULSE RATE.	URINE.	REMARKS.
Nov. 29		84	18	Cough and shortness of breath troublesome.
Dec. 1		88	30	
3		90	36	
5	Tr. Digit.	66	34	
7	5i p.d.	86	30	
8		78	22	Feels weaker.
9		100	32	Cough very troublesome, still giddiness.
10		92	19	
11	5vi Digit. stopped	100	22	Headache. No appetite. Vomited, chest feels tight.
12		108	30	
13		96	29	
15		80	32	
17		82	22	
19		86	20	Very short of breath.

CASE 41, female, aged 28. Tuberculosis of both lungs. Pyrexia.

Housewife, suffering from advanced pulmonary tuberculosis of both lungs with considerable evidence of excavation. Temperature continuously raised between 100 and 103 degrees Fahr..

DATE.	DRUG.	PULSE RATE.	REMARKS.
Oct.			
23		82	
24	Tr. digit. \mathfrak{z} i p.d.	84	
25	"	110	
26		100	Vomited.
27	"	100	Vomited.
28	Tr. digit. m. 20	110	Digitalis stopped.
29		120	
30			No further vomiting.

CASE 42, female, aged 30. *Tuberculosis of both lungs. Pyrexia. Digitalis had no effect upon the heart.*

Housewife. Suffering from advanced pulmonary tuberculosis of both lungs with evidence of excavation below the left clavicle. A pyrexial case, in which the temperature was uninfluenced by digitalis, the average evening temperature being 100 Fahr..

The pulse rate before digitalis was given (October the 23rd) was 88.

DATE.	DRUG.	PULSE RATE.	REMARKS.
Oct.			
24	Digit. \mathfrak{z} i p.d.	90	
25		90	
26		80	
27		100	Slight headache.
28		100	Nausea.
29		90	Nausea.
30	Digit. stopped	96	Nausea.
31		96	

CASE 43, female, aged 36. *Tuberculosis of both lungs. Pyrexia.*

Book-keeper, suffering from advanced pulmonary tuberculosis of both lungs with continuously raised temperature, 99 to 101 degrees Fahr..

DATE.	DRUG.	PULSE RATE.	REMARKS.
Oct.			
23	Before digit.	96	
24	Digit. m. 20 t.d.	90	
25		100	
26	"	80	
27		100	Headache, felt sick.
28	Digit. m. 10 t.d.	90	
29		100	Patient felt sick and wretched this morning.
30	Digit. stopped	90	Patient still feels a little sick.

CONCLUSIONS.

The careful analysis of the symptoms of patients to whom digitalis has been administered brings out the fact that individuals react differently to the drug. So far as the heart is concerned, the difference is partly dependent on the nature of the lesion with which the heart is affected.

Cases of auricular fibrillation are more readily and more markedly affected than cases with the normal rhythm.

Digitalis, in a proportion of cases with the normal rhythm, affects the auriculo-ventricular bundle more particularly, producing partial heart-block.

It is suggested that the susceptibility of cases of auricular fibrillation may result from the tendency of the digitalis to affect the bundle, the change in the auricular condition rendering the bundle more susceptible to the influence of the digitalis. It is possible that in slowing the heart's rate, the digitalis acts by stimulating the vagus nerve. Digitalis tends to induce auricular fibrillation.

In two cases of tachycardia, arising from an abnormal source, digitalis caused the heart to revert to a normal rhythm, first inducing fibrillation of the auricle.

The diuretic effects of digitalis may be produced with no perceptible change in the heart.

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FIG. 52. A
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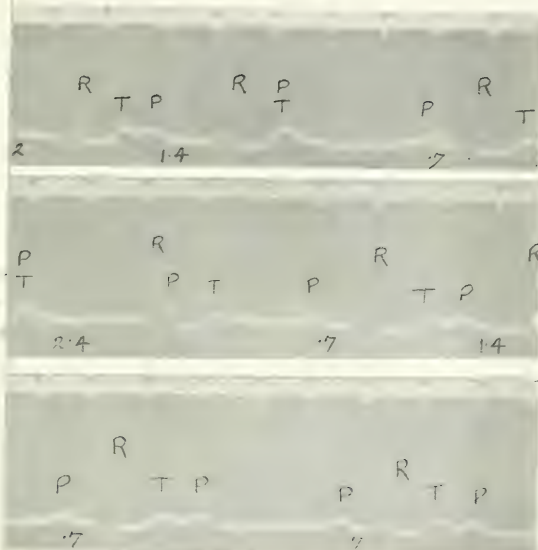


FIG. 52.



Fig. 53.



Fig. 54.

Fig. 53. An
finger the
the absent
oscillations



Fig. 54. An
cular beats
contraction
no auricul

Fig. 55.



Fig. 55. An
absent. T
cardiogram

Fig. 56. (CA
cardia. T
lead from
wavy line





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